Professional Learning Communities (PLCs) as a Means for School-Based Science Curriculum Change

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ABSTRACT

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The challenge of school-based science curriculum change and educational reform is often presented to science teachers and departments who are not necessarily prepared for the complexity of considerations that change movements require. The development of a Professional Learning Community (PLC) focused on a science department's curriculum change efforts, may provide the necessary tools to foster sustainable school-based curriculum science changes. This research presents a case study of an evolving science department PLC consisting of 10 middle school science teachers from the same middle school and their efforts of school-based science curriculum change. A transformative mixed model case study with qualitative data and deepened by quantitative analysis, was chosen to guide the investigation. Collected data worked to document the essential developmental steps, the occurrence and frequency of the five essential dimensions of successful PLCs, and the influences the science department PLC had on the middle school science department's progression through school-based science curriculum change, and the barriers, struggles and inhibiting actions of the science department PLC. Findings indicated that a science department PLC was unique in that it allowed for a focal science departmental lens of science curriculum change to be applied to the structure and function of the PLC and therefore the process, proceedings, and results were directly aligned to and driven by the science department. The science PLC, while logically difficult to set-up and maintain, became a professional science forum where the

middle school science teachers were exposed to new science teaching and learning knowledge, explored new science standards, discussed effects on student science learning, designed and critically analyzed science curriculum change application. Conclusions resulted in the science department PLC as an identified tool providing the ability for science departmental actions to lead to outcomes of science curriculum change improvements with the consideration but not the dictation of the larger school community and state agendas. Thus, the study’s results work to fuse previously separated research on general PLCs and curriculum change efforts into a cohesive understanding of the unexplored potential of a science PLC and school-based science curriculum change.

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I would also like to acknowledge science teachers, without whom I would not have been inspired to pursue this journey. Science teachers introduce their students to the investigatory pursuit of knowledge. Science via science teachers can therefore open the doors of scientific wonder and inspiration to students. It was my own science teachers (both formal and informal) that sparked a fire that has burned a lifetime, continually feed by my pursuit of further my knowledge and education. I hope to be that type of science teacher and I hope my research works to support science teachers and their efforts!

DEDICATION

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CHAPTER 1: INTRODUCTION

Science Department PLC as a Means for Science Curriculum Change

School-based curriculum reforms position teachers at the core of change. Research on teachers' content and classroom knowledge, promotes teachers as a tool to inform curriculum development (Begg, 1998; Howells, 2003; Print, 1993) and school-based curriculum change. The direct benefit of changes developed by and through a school's teachers is curriculum aligned to the interests and needs of a particular student population and school community. Curriculum is than based on local context and relevant to the "place" where students live and learn (Gruenewald, 2003). It is the teachers who are the tools, means, and key to developing appropriate, motivating, and relevant curriculum (Bolstad, 2004).

There are, though, many barriers to teacher-developed and implemented school-based curriculum reform; "the characteristics, traditions, and organizational dynamics of school systems are more or less lethal obstacles to achieving even modest, narrow goals" (Sarason, 1990, p. 12). Because teachers and school departments are not prepared for or supported to take on the complexity of considerations that change movements require to take root and grow within the school community, the unfortunate result is the failure to make any meaningful changes. Too often changes and reforms are un-sustained, unobtainable, and unsupported (Blumenfeld, Fishman, Krajcik, & Marx 2000; Burden & Hunt, 2010; Cuban, 1992; Firestone & Corbett, 1989; Fishman & Krajcik, 2003; Fullan

& Miles, 1992; Henderson, Finkelstein, & Beach, 2010; Sarason, 1990; Sherman, 2009; Sirotnk & Clar, 1998).

Science curriculum changes in particular have experienced various perspectives and influences over the decades ranging from external political pressures to internal pedagogical trends implemented by schools themselves (Sherman, 2009). Yet science teachers have experienced little input regarding the implementation of such change reforms:

> When one has no stake in the way things are, when one's needs or opinions are provided no forum, when one sees oneself as the object of unilateral actions, it takes no particular wisdom to suggest that one would rather be elsewhere. (Sarason, 1990, p. 83)

It is surprising then that there is "limited empirical literature to date exploring teacher educators' roles or influence…to act both as contributors to, and critics of, curricular reform, given their expertise and relative independence of operational aspects of educational systems" (Brian & Doherty, 2012, p. 54). Teachers' knowledge and expertise are being underutilized particularly in areas of need such as science curriculum and achievement. Studies and research on curriculum change and school reforms in general have focused on the role of classroom teachers in set curricular reform or on the success/failure of enacting reform changes. But lacking is research that documents the role and process of science teachers and departments in mediating curriculum to address science change movements and reform. Lacking as well is research on the means to support science teachers, departments, and schools throughout the complex and multifaceted task of science curriculum changes. There is need for a science teacher support system that allows for the continued investigation, reinforcement, reflection, and development of school-based science curriculum changes developed by teachers instead of forced onto teachers, as previously unsuccessful top-down science reform movements have done.

It has been suggested that a Professional Learning Community (PLC) may provide the necessary tools required to foster sustainable school-based curriculum change:

> Instead of bringing about "quick fixes" of superficial change, they [PLCs] are sufficiently flexible and adaptable to create and support sustainable improvements that last over time because, through teamwork and dispersed leadership, they build the professorial capacity to solve problems and make decisions expeditiously. (Giles & Hargreaves, 2006, p. 126)

The PLC essentially becomes part of the natural interactions between the major stakeholders (teachers, administrators, curriculum, and reforms) influencing science curriculum changes and student science learning experiences. The PLC provides the opportunity to fuse the previously separate factors (teachers, administrators, curriculum, and reforms) with the united focus and vision of enhancing student learning in science. The following illustration (Figure 1) attempts to display visually the various interactions and influences in and between the separate stakeholders and the position of the PLC within the school structure, as suggested by research and through the authors' interpretation. The PLC functions within the structure of the school and, therefore, within school culture, with the focal point being the students. By centering on the students, the PLC is able to connect the teachers, administrators, reform movements, and science curriculum. Each of these entities has a stake and influencing role on each other and the students. The PLC works to utilize these influences by connecting all the stakeholders for the collective purpose of student focus. Each entity now continues its influencing role while influencing the PLC, which in turn influences each entity with the accepted vision of working towards improved science teaching and student learning. There are no longer separate entities; all are connected, interdependent, and collaborating through the PLC.

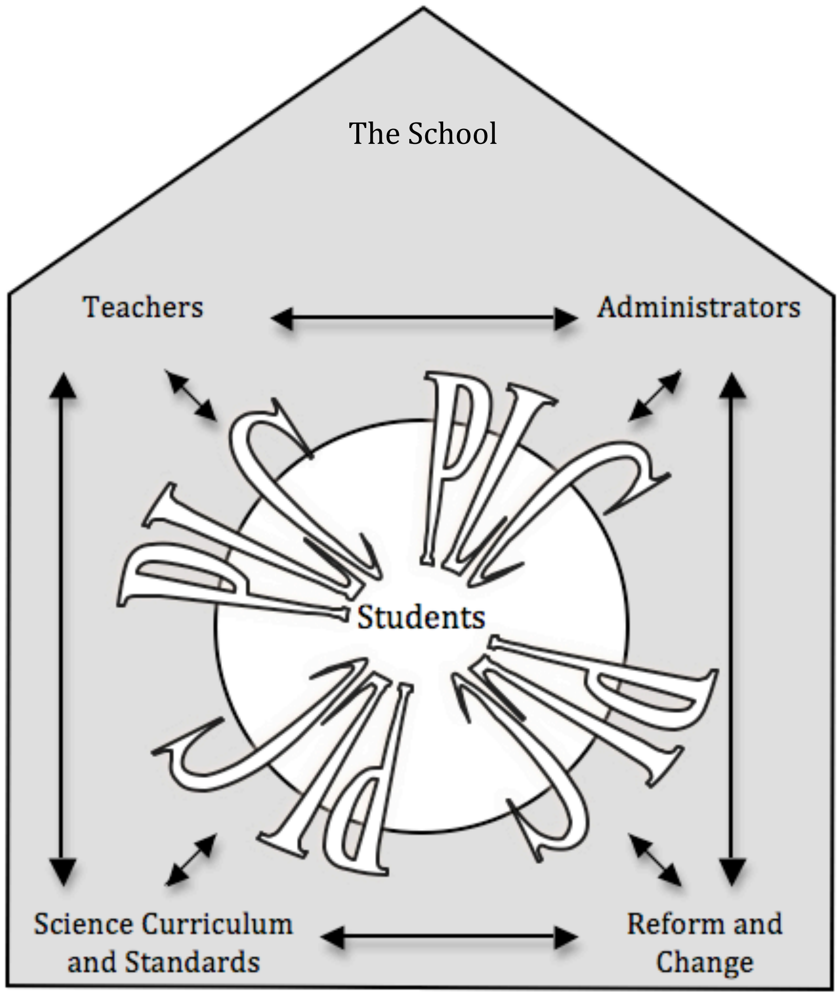


Figure 1. The Role of the Science Department PLC Within the School Structure. Research-suggested position of the PLC within the school system, displaying the PLC's ability to connect previously separate influencing entities for the purpose of increased student focus and the interconnection and relations of the PLC entities. (Science Department PLC figure, created by Browne, 2013).

Giles and Hargreaves (2006) have researched and outlined the possibility of learning organizations and PLCs influencing attrition of school change. PLCs used within and by schools have key components essential to successful change motions:

> PLCs in schools emphasize three key components: collaborative work and discussion among the school's professionals, a strong and consistent focus on teaching and learning within that collaborative work, and the collection and use of assessments and other data to inquire into and evaluate progress over time. (Giles & Hargreaves, 2006, p. 126)

Thus far, research on the practical benefits of PLCs have focused on teacher learning in the context of the PLC, not on empirical evidence of the effects of PLCs in the specific context of science. How PLCs can be utilized, developed, and sustained by science departments enacting and fostering school-based science curriculum change developed by the teachers has not been addressed or explored. Research documenting the actual steps of developing and maintaining successful school science PLCs is scarce to nonexistent as well. Without such documentation, there is a gap in the literature on the merging of PLCs and science departments involved in school-based science curriculum change, with the focus on bottom-up science curriculum change development.

Research Study

Given the challenge of educational reform a current reality, the need for school-based science curriculum changes to improve science teaching and learning, and the potential function of PLCs in mind, this research attempted to document the development and evolution of a middle school science department PLC engaged in school-based science curriculum change. This research works at addressing the previously unexplored coupling of PLCs, bottom-up school-based science curriculum changes, and science teaching and learning.

Hypothesis and Research Questions

To address the need for science curriculum reform and to maintain the role of the teacher in the reform process to encourage bottom-up, proximal curriculum and pedagogical changes, this research proposed the development of a science department PLC. The PLC is the hypothesized tool to empower the science department to make school-based science curriculum changes. To document the development and possible role and influences the science PLC might have on enhancing or hindering a middle school science department's progression through school-based science curriculum change, the following questions were designed:

1. How did the five dimensions of successful PLCs manifest and evolve as the science PLC progressed?
2. What were the actions and outcomes of a PLC focused specifically on a science department?
3. How did the actions of the science PLC facilitate or impede the science department's goals of school-based science curriculum change?
4. What external and internal factors facilitated or inhibited the functions of the science PLC and science curriculum change goals?

This research was framed as a case study, documenting a PLC bounded by middle school science department participants for two years of data collection in a suburban middle school. As the PLC worked towards school-based science curriculum reform, a transformative mixed methods approach was applied. The study utilized concurrent data collection of qualitative and quantitative data to allow for triangulation and arrive at a deep and descriptive understanding of findings regarding the science department's PLC development and the role of the evolving PLC in the science department's comprehension of science curriculum change and sustainable science pedagogical changes.

This study used pre- and post-Likert scale surveys and set analytical coding to measure the relationship between the frequency and appearance of the five dimensions of successful PLCs (Hipp & Huffman, 2007) as the PLC developed over time. The use of the PLC for school-based science curriculum change was explored through the PLC meeting transcripts, researcher field notes, and participant reflections via open-ended questions. By combining both qualitative and quantitative data, it was possible to obtain a better understanding of the relationship between the dimensions of a successful PLC and the process of school-based science curriculum change that occurred in conjunction with the science department PLC. Science department PLCs may be the tool and support system that is currently lacking for science teachers and departments faced with the complex task of school-based science curriculum change.

Significance of Research

PLCs may be of valuable use to science departments as a means of faculty support, motivation, reflection, and meaningful development of school-based science curriculum change. Such a merging of PLCs, school-based curriculum change, and science has not been previously explored and data collected from this study can work towards filling the gaps in the PLC literature relating to school-based science curriculum change. For example, the research holds the potential to answer previously unanswered questions about the possible role PLCs can play in science reform, school-based science curriculum changes, and department or subject PLCs working towards reform efforts.

This research can inform the literature about the role PLCs can play in supporting or undermining bottom-up curriculum development and proximal pedagogy by teachers. The research as well can aid scholars, practitioners, teachers, professionals, and community members in their understanding of the role of PLCs in bottom-up science curriculum development, using the lens of the new science framework and the necessity of considering multiple stakeholders when developing a proximal science curriculum that strives to develop 21st century student science learning and increased science literacy.

CHAPTER 2: LITERATURE REVIEW

The Call for Education Reform

The current national climate of uncertainty in the U.S. is a reflection of the country's labor market insecurity, economic instability, unemployment numbers, and rapid technological advances making previous practices obsolete in this new digitally connected and global society. As the U.S. struggles to maintain its hold as a world leader, employers, governmental agencies, and local communities are increasingly demanding school systems to boost the achievement levels of the next generation of the American workforce. Demands include public displays of documentation and demonstration that school curriculum and teachers embody coherent courses of study, with teacher delivery integrating intended learning outcomes that produce high scores on standardized testing at the state, national, and international levels.

Education and school systems are called to define the path towards relevance, innovation, and progression for the U.S. Historically, such a call without fail heralds the coming of educational reform movements, as Sherman (2009) summarized: "…attempts to improve education during the past forty years under the banner of 'educational reform' have included political initiatives generated externally…as well as pedagogical trends and movements conceived and implemented by educators themselves" (p. 41). An example with effects still felt by educators today was the educational standards movement reform agenda of the 1980s, which continued into the 1990s with curriculum guidelines, science frameworks, and science and mathematical reforms that appeared from state legislatures as if from a conveyor belt. At the time, the standards movement was intending to restore education in the U.S. through standards and accountability. The public's embrace of the standards movement and the need to demonstrate increased standard achievement levels gave birth to a new age of standardized testing. The increased use of and reliance on high-stakes standardized tests has had a wide range of effects on curriculum, pedagogy, and even school culture and climate (Madaus, 1988).

In such a climate of unrest, history has proven both that educational reforms are an undeniable result and reforms are followed by their failure to succeed or be sustained. The most common response to educational insecurity is curriculum reform; thus, tools, methods, and practices are needed to prepare schools and their teachers for the predictable change movements that are barreling towards subject-level curriculum, standards, teachers, school systems, and students learning outcomes. In the presence of such reforms, school and teacher strategies responding to and developing curricula that provide a coherent, aligned educational experience for students to address the increasing calls and demands for accountability, efficiency, and transparency (Veltri et al., 2011) are necessary for survival.

The Call for Curriculum Reform

What is meant by curriculum? Curriculum as a definition is complex, with multifaceted meanings that work to explain the educational experience provided to students via the school systems and ultimately the teachers. Curriculum outlines the why, what, when, where, how, and whom of learning (Braslavsky, 2003). Perhaps one of the most comprehensive descriptions of curriculum is provided by Braslavsky, the director of the International Bureau of Education:

> Using educational concepts, we can say that the curriculum defines the educational foundations and contents, their sequencing in relation to the amount of time available for the learning experiences, the characteristics of the teaching institutions, the characteristics of the learning experiences, in particular from the point of view of methods to be used, the resources for learning and teaching (e.g. textbooks and new technologies), evaluation and teachers' profiles. (Braslavsky, 2003, p. 1)

Thus, the reason curriculum is often the focus of reform is because it directly impacts student learning outcomes and achievement levels.

The Problem with Curriculum Change

When considering the curriculum development process and changes towards improvement, the question becomes: What is the problem with curriculum reform, curriculum development or change? Historically, the problem with curriculum changes and programs in the U.S. is that it has followed the path of top-down curriculum dissemination. When the curriculum development process proceeds from the top and moves downward (for example, descending from governments and representatives), it is termed "top-down" curriculum development.

> In this case, curriculum development processes can be defined through four phases: (i) the curriculum presented to teachers; (ii) the curriculum adopted by teachers; (iii) the curriculum assimilated by learners; and (iv) the evaluated curriculum. The majority of centralized countries follow this type of curriculum development process. (Braslavsky, 2003, p. 3)

Tienken (2011) pointed out that such curriculum has the weakest influence on student learning: "When curriculum is treated as a distal variable—occurring distant from the student, handed down from on *high*…its influence is weakened" (p. 61). Wang et al. (1993) have argued that when curriculum was a "proximal variable" (p. 261), it had a greater influence on the educational experience, as shown by student achievement. When the curriculum was closely designed around and for the student, there was a greater influence on learning. This type of curriculum development process can move from individuals and groups within educational institutions or from the bottom upwards (i.e., “bottom-up” curriculum development).

> In this case as well, four different phases can be identified: (i) what the society or the parents want; (ii) responses provided by teachers in the schools; (iii) the collection of these responses and the effort to identify some common aspects; and (iv) the development of common standards and their evaluation…. This type of curriculum development process or processes, are carried out in each school in the context of its community, but without necessarily taking into consideration the developments adopted by other schools or institutions. (Braslavsky, 2003, p. 3)

National policy mandates tend to have little influence on student learning because the curriculum is distal to the actual learning process (Wang et al., 1993). Tienken (2011) claimed that support for curriculum as a proximal variable can be found in the works and writings of Francis Parker, John Dewey, Horace Mann, Ralph Tyler, and Hilda Taba, and from the studies of Aikin (Eight-Year Study, 1942), Collings (1923), Thorndike (1924), Wrightstone (1936), and Jersild et al. (1941). Tieken (2011) professed that this wealth of insight and research, coupled with the results from current educational curriculum achievement, “demonstrated that there is not one best curriculum path for students…and standardized curricula is not necessary to achieve superior results in elementary and secondary schools” (p. 61).

A single curriculum for all children does not seem logical when considering the individual needs of students vary and the diversity of student learners and populations across the U.S. It would seem more prudent to encourage curriculum diversity to enhance the learning experiences of such diverse needs.

> We should be trying to help students explore and enrich their intellectual and social growth, not constraining them or funneling them into a small set of subjects…. Mandating that everyone follow the same set of standards and perform as the same level of achievement guarantees that everyone will not get what they need…. We should instead respect the differences among children, not try to extinguish them. (Tienken, 2011, p. 63)

The main issue with top-down initiatives is the lack of ownership and contextualization in the local school district and for the local student population. As Harris and Hopkins (1999) pointed out, local implementation determines learning outcomes and student achievement: "it is becoming increasing apparent that centralized policy initiatives have little impact on student achievement…. Centralized policy can best set a direction, a framework for action, but it is local implementation that determines student outcomes" (p. 257). Teachers must have a role in the curriculum development process. The success of any current or future curriculum change is in the success of the degree of congruence between the planned and the operational curricula in a particular context and the degree of learning taking place (Punia, 1992). If curriculum reform efforts are based on the intended curricula of researchers rather than the enacted curricula of teachers, the disparity inhibits education reform (Lynch, 1997). As Fullan (1993) wrote, "teachers' capacities to deal with change learn from it will be critical for the future development of societies. They are not now in a position to play this role" (p. 11). To return to teachers their voice and power over their curricula, and to avoid the pitfalls of top-down curriculum development, movement must be towards bottom-up curriculum development and reform, towards school-based curriculum reform efforts!

Reform via School-Based Curriculum Change

School-based curriculum change as an educational philosophy was defined by Bezzina (1991) as "a process in which some or all of the members of a school community plan, implement and/or evaluate an aspect or aspects of the curriculum" (p. 40). This process may involve adapting an existing curricula and/or adopting a new curriculum, as long as the change efforts are collaborative. This collaboration is central to school-based curriculum change because once a curriculum problem or issue is identified, "the resolution is carried out by teachers, with or without outside advice, as they are considered to be those educators most aware of student needs" (Print, 1993, p. 20). This idea of a collaboration of teachers working as developers of curriculum, not simply as conduits for curriculum (Bezzina, 1991), has both historical and current educational merit. Examples are found in research arguments advocating teachers' content and classroom knowledge as tools to inform curriculum development (Begg, 1998; Elliot, 1997; Howells, 2003; Print, 1993), thus exemplifying the teachers' role in school-based curriculum change and bottom-up curriculum development.

Bolstad (2004) outlined four reasons to increase the use of school-based curriculum development (SBCD):

> SBCD provides a mechanism for schools to:
> 1. Better meet the needs and interests of students and the school community;
> 2. Embed school learning in local contexts, knowledge, and resources, to meet local and national aspirations;
> 3. Be responsive to new ideas and technologies in education; and
> 4. Take advantage of opportunities created by new curriculum and assessment structures. (pp. 7-8)

Curriculum changes are essentially "efforts to reform classroom instruction and create learning environments that promote…students' thinking skills, motivational dispositions, and knowledge" (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000,

p. 149). Research suggests that students learn by constructing their own meaning and knowledge from their experiences; this should be the basis for making instruction more effective. Thus, when considering school-based curriculum change as a source of curriculum and pedagogy, the reforms are rooted in constructivist ideals (Blumenfeld et al., 2000). The assumption is that students require the opportunity to interact with concepts to form true understanding. Teachers working with students are directly in control of instruction and learning environments and therefore are key to curriculum change efforts supported by best practices. The teachers (bottom-up development) then should be directly involved in designing the curriculum (proximal curriculum development) they are responsible to deliver effectively to promote the best student understanding and learning.

The place for school-based curriculum change within educational reforms has thus been established through bottom-up curriculum development and proximal curriculum designed for particular student populations and school cultures. However, the success of such reforms is a major consideration prior to enactment given that there are many barriers to school-based science curriculum reform. "In order for changes to occur…school personnel must change…through the programs and practices currently in place and supported by the school system" (Bybee, 1995, p. 5). Burden and Hunt (2010) found in recent years that teachers have experienced reduced levels of curricula freedom (particularly in biology); "there has been the loss in opportunities for teachers to become involved…in some of the more innovative curriculum" (p. 100). This occurrence has been directly linked to standardized curriculum. "A compliance culture has been imposed on schools.… Teachers have been expected to becomes 'deliverers' of curricula devised by others” (p. 100). This expectation of teachers as being mere conduits of curriculum is counterproductive, to say the least, for meaningful curriculum development and reform.

Another consideration of school-based curriculum change is the logistical functions of how to go about managing curriculum change movements in ways that lead to success. Bezzina (1991) pointed out the necessary support structures and foundations needed for an outlined set of curriculum goals and priorities: regular meetings, time for curriculum development activities, linkage between teachers and the curriculum change, and at times use of expertise from outside personnel. Therefore, when considering school-based curriculum change:

> Critical factors include the nature and structure of the curriculum, the degree to which schools are able to make their own decisions about curriculum and other matters, schools’ accountability for demonstrating the outcomes of their curriculum practices for students, the expected role of teachers in curriculum development, and the expected or potential role of other people in school curriculum development. (Bolstad, 2004, p. 14)

School-based curriculum reform places teachers directly at the core of change. This allows for change that aligns curriculum to the interests and needs of a particular student population and school community. Curriculum is based on local context relevant to the “place” where students live and learn (Gruenewald, 2003). Teachers are a tool and a means to developing appropriate, motivating, and relevant curriculum (Bolstad, 2004). School-based curriculum reform provides a bottom-up development process proximal due to its design by teachers within the school system and particular school culture.

Science Education Reform and Change

School-Based Science Curriculum Reform

Current support for the reform of science curriculum is unprecedented in the history of American education (Bybee, 1995; DeBoer, 2000). The claim is students need to be science-literate in order to compete in the global economy and maintain the validity of the U.S. as a major competitive and innovative country in the world. The published report entitled *A Nation at Risk: The Imperative for Educational Reform* (National Commission on Excellence in Education, 1983) argued that academic standards in the U.S. had fallen, as shown by American students' low-test scores, particularly in math and science. This was linked directly to the country's declining economic position in the global economy. Following *A Nation at Risk*, a barrage of research, articles, reports, books, agendas, and frameworks were published, each heralding the need to reform the current education system in the U.S. Depending on the report, the means to enhance science achievement included updating scientific and technological knowledge, STEM education, application of contemporary teaching and learning theories, improved equity, inquiry learning, focus on skill and practices of science, NOS (nature of science), and increased scientific literacy for the future workforce. However, the collective message was clear: "the need for reform was based on the conviction that the U.S. had not responded as quickly as other countries in preparing its young people for a world in which science and technology play such a large part, and now the U.S. needs to catch up" (DeBoer, 2000, p. 589). The ultimate reform solution was proclaimed to be a more rigorous academic curriculum and higher standards for all students to be shown through assessment and accountability. "Although the standards movements have been important in helping develop a sense of good science learning and teaching, there are still far too many visions at play" (National Center for Improving Student Learning & Achievement in Mathematics & Science, 1999, p. 9).

In 1989, in response to the call for standards-based curriculum reform, the American Association for the Advancement of Science (AAAS) published Project 2061's *Science for All Americans* to clarify the goals of science education to educators and to make scientific literacy attainable for all students. In the mid-1990s, the National Science Education Standards (NRC, 1996) was part of the U.S. government's approach to educational reform, which involved setting national goals and standards for meeting those outlines. The U.S. government as well declared that American students should be number one in the world on tests of science knowledge by the year 2000. Current trends continue to support "test results as accepted and valid indicators of the current state of affairs and sufficient justification for state and federal governments to exert more control over the direction the science education program should take" (DeBoer, 2000, p. 594).

From this state of unrest in science education surfaced mixed messages regarding science education reform and the role of the teacher and educator in school-based science curriculum change. As DeBoer (2000) aptly pointed out:

> …Although the authors of the standards make it clear that the content standards do not constitute a curriculum and the implementation is the responsibility of individual teachers, they also say that scientific literacy is *defined* by the content standards and that none of the standards should be omitted. (p. 595)

Kyle (1996) also pointed out that this standards approach has effectively stripped teachers of being active agents in educational policy and curriculum decisions. Wood (1988) commented on the negative effect of an emphasis on standards and high-stakes testing as it essentially "constrains and routinizes the teachers' behavior, causing them to violate their own standards of good teaching…. The classroom interaction is structured in such a way as to inhibit students from asking questions…to 'get through' the materials so students will score well on tests" (p. 631).

One begins to lose the proverbial forest with an in-depth inspection of the trees, and so it has been with the science education reform agenda. The undeniable fact is the need for science curriculum reform and change. This is because science today and the role of science within our lives is changing; therefore, the key factor in successful changes will depend on the types of changes made, the means of implementation, and the impacts on student learning outcomes.

Changing Science, Changing Science Teaching

Throughout the long and complex history of science educational reform, efforts have been aimed at bridging the gap between real-world science application and the K-12 science classroom education experience via the teaching of science. The continued struggle to bring meaningful science pedagogy into schools is complicated by the growth and development of the sciences and of science teaching and learning developments. Couple contemporary evolutions in science knowledge with the changing image of the practice of science (Hurd, 1997), revolutionary changes in societies, the technology boom, and research and development in science education, science, and the science of learning (Duschl, Schweingruber, & Shouse, 2007), and we realize that science and the ways of understanding how it is learned and taught are rapidly changing.

The understanding of science, science knowledge development, and science education has progressed significantly since the National Science Foundation's curricula efforts of the 1960s, not to mention the 1980s and 1990s push towards systemic and standards-based reform; "philosophers of science have challenged fundamental assumptions about what science is and how it operates" (Duschl et al., 2007, p. 18). Contemporary science has advanced because of enhanced instrumentation, computer technology, and deepened scientific knowledge giving rise to models of natural phenomena grounded in mathematical, statistical, probabilistic, and computational reasoning (Duschl et al., 2007). Science has transitioned from a single-disciplinary based study to cross-disciplinary studies:

> The disciplinary boundaries between the life and the physical sciences have blurred, as have the boundaries between scientific and technological development, with the emergence of new fields, such as biochemistry, geophysics, bioinformatics, computational biology, advanced chemical synthesis, and nanoscience. (Duschl et al., 2007, p. 18)

Therefore, the traditional teaching of the core sciences as individual disciplines of biology, chemistry, physics, and earth science is found only in school systems. As well, the practice of science is changing: "less attention is being devoted to the establishment of new theories and laws…. Today more attention is focused on the functional aspects of science/technology as it relates to human welfare, economic development, social progress, and the quality of life" (Hurd, 1997, p. 409). This trend explains in part how science research is shifting. Science philosophers and scholars in the history of science and sociology of science "see scientific inquiry as a model or theory based, increasingly conducted by groups and communities of scientists" (Duschl et al., 2007, p. 18). Research in science/technology is therefore managed by teams of researchers representing a mix of scientists from both the natural and social sciences, not to mention the essential computer expert on the research team. "The team approach in the contemporary practice of science/technology is viewed as a cognitive system with a greater potential for increasing the fertility of hypothesis and discovery than an individual working alone" (Hurd, 1997, p. 410).

The emerging perspectives on the teaching and learning of science have further developed the expectations of what a competent or scientifically literate student has the capacity to do. "Contemporary views of learning prize understanding and application of knowledge in use" (Duschl et al., 2007, p. 19). Scientifically-literate students are those who can apply ideas in diverse situations, identify patterns and connections between concepts, ask questions, challenge claims, change perspectives and ideas with evidence, and communicate their thoughts. The understanding of learning environments has changed too; it is understood that students learn through various modes of multisensory interactions, which include books, television, the Internet, informal educational settings, outdoor experiences, and didactic interactions with peers and adults. It is "through group processes, they share and develop their understanding of and relationship to science" (Duschl et al., 2007, p. 19).

There is an alarming need for science curriculum change that reflects the ongoing developments in science, science practices, and science teaching and learning; the current approach is simply not working.

> The new and emerging perspectives on science learning raise questions about the appropriateness of the nation's current approach to science education… Standards, curricula, and textbooks that do not reflect knowledge about students learning of science will limit what they can learn. Similarly, standards and curricula that are too broad will lead to an unnecessary diffuse instructional effort. (Duschl et al., 2007, p. 20)

To transform science education and echo the evolution and developmental trends of the academic and research sciences, cognitive sciences, developmental psychology, science education, and learning theorists, Duschl et al. (2007) called for a reasonable set of learning objectives that target informed science practices and knowledge clearly and coherently, considering the understanding of science knowledge development, teaching, and learning.

If the sciences and the understanding of learning those sciences are changing, so too must the teaching of science change to keep up. Science curriculum reform is needed. Science curriculum and pedagogy must move away from traditional science instruction towards current research on science learning, which works to provide a curriculum that aids students' ability to develop the skills necessary to deal with the changing practices of science and technology. But as Duschl et al. (2007) cautioned, "as educators, researchers, and policy makers tackle these problems, new and old, they will require clear guidance" (p. 20).

A New Science Framework for K-12 Science Education

In response to the call for science curriculum and standards reform, the National Research Council (NRC) of the National Academies, whose members are drawn from the National Academy of Science, the National Academy of Engineering, and the Institute of Medicine, began the initial step of creating new standards in K-12 science education. The reason for the new science standards, according to the NRC (2012), are: (a) in the 15 years since the last national effort, progressions have been made in the sciences and educational developments on the learning and teaching of sciences which can work to "revitalize science education," and (b) it is the opportune moment because many states are open to adopting common standards, as evident by the common core in mathematics and language arts.

> The framework represents the first step in a process that should inform state-level decisions and provide a research-grounded basis for improving science teaching and learning across the country. It is intended to guide standards developers, curriculum designers, assessment developers, state and district science administrators, professionals responsible for science teacher education, and science educators working in informal settings. (NRC, 2012, pp. 2-4)

The types of changes the framework proposed were to attain greater coherence in K-12 science education by: having science education represent a development progression throughout the years of school science, focusing on a limited number of core ideas within and across science disciplines, and learning about science and engineering through both knowledge and practices (NRC, 2012).

In light of the *Framework for K-12 Science Education* (NRC, 2012), in conjunction with the completion of the *Next Generation Science Standards* (NGSS; Achieve, et al., 2013) in March 2013, it behooves science departments to critically review their current science curriculum through the lens of the new framework guidelines. The goals of the framework and standards are clear: this will be the science curriculum standard of the future and science educators should be ready. To put teachers at the forefront of such a change, school-based science curriculum changes can be initiated as a preemptive move to both protect and ensure the local teachers' role in the evaluation and enactment of the *Framework* and NGSS. Teachers must be sure to consider how the new framework translates to curriculum and pedagogical instruction for their school community, culture, and student population. In other words, teachers must maintain their role in the curriculum development process (bottom-up) in light of these new reform movements in science education to ensure meaningful change for their students' (proximal pedagogy) learning and achievement.

Maintaining the Science Teacher in Science Curriculum Change Efforts

Ensuring bottom-up curriculum development and proximal pedagogy in the face of a top-down science framework and standards is an immense challenge to school-based science curriculum change and reform. What is needed is a way or means for teachers to maintain their voice, input, and expertise in going about proximal pedagogical curriculum changes within their school communities. Keys and Bryan (2001) claimed that successful and enduring science curriculum reforms need teachers to be involved in the design and implementation of new science curricula. The teachers must be the link between the reform movements and the curriculum affecting students' learning and achievement. "Involving teachers from early stages contributes to the design of curriculum innovations from an implementation perspective" (Roblin et al., 2012, p. 6). Teacher involvement can entail anything from adopting and reflecting on previously developed units by science curriculum experts (Bennett & Lubben, 2006) to designing completely new curriculum (Eilks et al., 2004). Roblin et al. (2012) identified "the importance of involving (groups of) teachers in the design of curriculum innovations, either proactively (by participating in the design of curriculum materials) or reactively (by providing feedback during pilot studies)" (p. 5). Teacher groups working together to empower curriculum and educational changes are more meaningful and can potentially sustain positive changes over time. One possible suggestion to aid teachers in such efforts is the development of Professional Learning Communities (PLCs):

> International evidence suggests that educational reform's progress depends on teachers' individual and collective capacity and its link with school-wide capacity for promoting pupils' learning. Building capacity is therefore critical. Capacity is a complex blend of motivation, skill, positive learning, organisational conditions and culture, and infrastructure of support. Put together, it gives individuals, groups, whole school communities and school systems the power to get involved in and sustain learning over time. Developing professional learning communities (PLCs) appears to hold considerable promise for capacity building for sustainable

improvement. (Stoll et al., 2006, p. 221)

From this connection, a new question arises as to whether PLCs can provide the means to maintain bottom-up curriculum development and proximal pedagogy designed by teachers.

Professional Learning Communities

"The most promising strategy for sustained, substantive school improvement is developing the ability of school personnel to function as professional learning communities" (DuFour & Eaker, 1998, p. xi). Learning within a community of professionals is a fairly recent concept and practice that has emerged from research on organizational theory and human relations literature (Huffman, 2003). As Huffman pointed out, PLCs are connected to Senge's (1990) learning organizations, where "people continually expand their capacity to create desired results, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free" (p. 3). PLCs are "places in which teachers pursue clear, shared purposes for student learning, engaged in collaborative activities to achieve their purposes, and take collective responsibility for student learning" (Sparks, 1999, p. 53). PLCs link directly to constructivism, according to Hunt (2009), by aligning to Burns, Menchaca, and Dimock's (2001) six principles important to constructivist learning theory: (a) learners bring prior knowledge and experiences, (b) knowledge construction is unique, (c) learning is active and reflective, (d) learning construction involves assimilation or reject, (e) social interaction allows for shared meaning, and (f) the learner mediates learning. Within the PLC, the members, while bringing their individual experience, construct knowledge and decisions through their collaborative interactions in working towards a common goal.

A growing body of evidence illustrates learning communities as provisions of faculty support, encouragement, and opportunity for meaningful development of learning and teaching (Proposer, 2001, 2003). “An effective PLC has the capacity to promote and sustain the learning of all professionals in the school community with the collective purpose of enhancing pupil learning” (Bolam et al., 2005, p. 145). As DuFour (2004) pointed out, “This simple shift—from a focus on teaching to a focus on learning—has profound implications for schools” (p. 6). Teachers agreeing to view their role as fostering “learning for all” essentially commit to a pledge to the success of each student (DuFour, 2004, p. 6). This paradigm shift then brings about profound changes, according to DuFour.

As the PLC progresses, three questions (DuFour, 2004) should guide the drive, direction, and next steps of the learning community:

1. What is it that we want each student to learn?
2. How will we know when each student has accomplished learning?
3. What is the response when students encounter difficulty learning?

These guiding questions encourage focus to the PLC’s goal, continuous reflection, and dedication to the success of student learning. To further promote continuous development and improvement, the PLC’s teachers should engage in data collection and analysis (Dudley, 1999). “The results-oriented PLC not only welcomes data but also turns data into useful and relevant information for staff” (DuFour, 2004, p. 10). In this sense, the PLC is a means of research, discussion, support, and growth for schools focused on enhancing student learning.

A review of theoretical frameworks related to PLCs lead to the identification of five dimensions essential to successful PLCs (Hipp & Huffman, 2007; Hord, 1997; Hunt, 2009; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006):

1. Shared and supportive leadership.
2. Shared values and vision.
3. Collective learning and application.
4. Supportive conditions.
5. Shared personal practice.

These features are echoed by Westheimer's (1999) review of contemporary theorists exploring community function including: shared beliefs and understandings, interaction and participation, interdependence, concern for individual and minority views, and meaningful relationships. The heart of a PLC is the notion of a "community" that is collaborative, focused on learning, and results-oriented. The members of the PLC hold to the common value or vision of the PLC and, with this unified front, work collectively towards their end goals.

Lave and Wenger (1991) explained that when they are part of a community of practice, participants gradually assimilate into a "culture of practice," leading to shared meanings, a sense of belonging, and increased understanding. This is essential because the community, or the collection of learners within the community, define the PLC. To succeed, PLCs must consider the learning culture in which it functions; without this consideration, according to Fullan (1992), all change attempts will fail. Thus, school culture influences the readiness and willingness to change. Support from principals and the administration is also essential to this step because the school utilizes these leadership roles in policies, procedures, and programs to support the PLC's endeavors. "In many PLCs, principals work with teachers in joint enquiry and provide opportunities for teachers to take on leadership roles related to bringing about changes in teaching and learning" (Stoll et al., 2006, p. 237). Thus, to coagulate the school culture, school administration, and educators into a cohesive PLC, it is essential to design a vision for the PLC. It is the PLC's "emergence of a strong, shared vision based on collective values that provides the foundation for…sustained school growth" (Huffman, 2003, p. 32).

The Barriers to and Considerations of PLC Development

Not surprisingly, the road to success is not paved with gold. Research on learning communities, professional communities, and PLCs exhibit the caution and considerations that must be undertaken prior to contemplating or establishing a community of learners. Case studies and research (Bolam et al., 2005; Bryk et al., 1999; Little, 2002; Stoll et al., 2006) continue to teach the "lesson in the difficulty of forming professional communities" (Scribner et al., 1999, p. 157). In fact, existing evidence on schools undertaking the development of successful PLCs has demonstrated a significant decline (Fink, 2000; Hargreaves & Giles, 2003; Imants, 2004; McMahon, 2001). Schools engaged in developing professional communities have demonstrated struggles with the ability to deal with the tensions that arise when they as a learning community, on one hand, try to focus on student learning, critical reflection, and collaborative decision making, and on the other hand, deal with the bureaucratic complications of hierarchy, accountability, rationalization, and control (Meltzoff, 1994; Minar & Greer, 1969). Therefore, any school or group of teachers wishing to develop professional communities will be faced with the rigorous task of taking on and negotiating through these tensions.

> Several issues influence the degree to which professional community was (or will be) achieved: (a) principal's leadership style and approach to school level change, (b) past events and occurrences remembered and passed on to new organizational members, (c) politics of allocating scare resources and (d) the persistent bureaucratic organization of schools. These issues form a serous dilemma when they surface as impediments reflecting school cultures that are incongruent with professional community. (Scribner et al., 1999, p. 154)

Often, a PLC cannot be formed, structured, and sustained because of such issues outlined above. Thus, each of these dilemmas, along with the research and reflection of other failing PLCs, warrants review and consideration before continuing the exploration of possible PLC outcomes.

Leadership: Principal Role and Faculty Perceptions

The principal's leadership approach is perhaps one of the most indicative initial influences on the establishment of a professional community within the school. Research illustrates how leadership actions can either facilitate or impede professional communities (Crowther, 2001; Gronn, 2000; Harris, 2003; Hord, 1997; Schein, 1992; Sergiovanni, 1994; Spillane, 2006; Stoll et al., 2006).

- Where the principal attempts to build trust and shared sense of purpose among the leadership team and faculty, the faculty's trust in the principal grows. The faculty will support the principal's initiatives as the principal supports the faculty's work.
- In cases where the principal abdicates initiatives, taking a hands-off approach, there was a negative affect on the development of the professional community. The principal did not facilitate norms, nor show the value of community, collaboration, and change.

- In other cases if the principals views were not consistent with the reality of the school culture and community. In actuality the professional community was perceived as a top-down construction, run by the principal advisory committee and leadership team. This ended in distancing the rest of faculty. The principal attempts to develop culture through the community had undesired and unforeseen directions. (Hargreaves, 1994; Scribner et al., 1999; Stoll et al., 2006)

McLaughlin and Talbert (2001) summarized the role of the principal in school community developments:

> For better or for worse, principals set conditions for teacher community by the ways in which they manage school resources, relate to teachers and students, support or inhibit social interaction and leadership in the faculty, respond to the broader policy context, and bring resources into the school. (p. 98)

Another leadership consideration is the faculty's perception of the leadership structures and the faculty role within the school system. If the faculty does not perceive that the school‘s decision-making processes encourage useful collaboration with teachers, reflective and meaningful dialogue between faculty and administrators, and a focus on student learning outcomes, then they will not see how their role in a community of any kind will make a difference in the change process (Hopkins, 2001). Thus, lacking faculty trust in leadership makes the establishment of an environment conducive to collaboration, reflective dialogue, and student focus (all critical elements of professional communities) difficult or even impossible to form (Scribner et al., 1999). Leadership then cannot be central to one individual or even one leadership group because of the complex nature of school systems, which depend on the reciprocal actions of many individuals for change

(Gronn, 2003). Needed is a distribution of leadership in conjunction with principals for joint action responses (Gibb, 1958; Gronn, 2000; Spillane, 2006; Stoll et al., 2006).

Leadership and specifically the principal's role are essential to the development of community. Principal leadership role and faculty perception must be considerations when identifying if a PLC can be established and useful within a particular school setting.

Organizational role considerations. The roles of faculty and administrators within a school system are often defined and passed on to new staff over time. These time-stamped school traditional views are major considerations for the development of professional communities as they are indicators of the school culture. Often, the views and perceptions of the roles of teachers and staff will be set and accepted positions. If these roles and positions are in contrast with the fundamental ideas of a community of professional learners, a huge barrier to the development and function of the professional community may arise or be insurmountable. Stoll et al. (2006) therefore maintained the argument that any attempt at school improvement that negates the school culture is doomed because school culture directly influences the readiness and ability of the school to change.

- In cases where teachers were organized on grade-level teams, the teachers were used to collaboration and shared leadership. These situations were more conducive to professional community development because positive relationships, collegiality, trust, and respect were already present between staff members. (Bryk & Schneider, 2002; Louis et al., 1995; Nias, Southworth & Yeomans, 1989).

- In cases where teachers reported teaching as isolated or where schools described dysfunctional relationships between staff interactions (Reynolds, 1996), community development was lacking. In situations with little communication or collaborative norms, teachers were unlikely to participate in community learning (Louis et al., 1995). In these situations, professional communities did not succeed (Scribner et al., 1999).

At the least, these perceptions are influential on the manner and extent to which the faculty can/will implement and develop the professional community.

Space, Time, and Funding Considerations

An undisputable challenge to the development of a professional community is the consideration of space, time, and funding for the PLC meetings (Louis & Leithwood, 1998; Stoll et al., 2006). It is a constant challenge for principals and leadership teams to secure and allocate the scarce resources (i.e., time, funding, personnel) available for developing and fostering the communities (Scribner et al., 1999). Competition for limited resources at the school and district level can become a contentious struggle to the development of learning communities. Each is discussed below.

<u>Space</u>

- The space and proximity of teachers within a learning community allowing for opportunities for teachers to work and explore teaching and learning are other key indicators of learning-centered schools (Dimmock, 2000). Professional exchanges increase when teachers are in closer proximity to each other's rooms, when they are in team teaching situations, and when there is a subject workroom in which staff can gather to converse (McGregor, 2003; Stoll et al., 2006).

Time

- Tensions can develop at schools between the district vision and school-level reform efforts. When considering funding, Scribner et al. (1999) pointed out that at the district level, there is a required amount of short-term measureable results to justify funding and resources, but PLCs are long-term tools of reflection that can lead to school change. Thus, direct and contrary goals lead to conflict. Policy-oriented change can be perceived as demands on the learning community (Karsten, Voncken, & Voorthuis, 2000), leading to stress and teacher disengagement (McMahon, 2000; Woods et. al., 1997).
- The structuring of time for community members to talk and conduct professional dialogue is a key indicator of learning communities (Louis et al., 1995; Stoll et al., 2006). In Scribner et al.'s (1999) investigation, success was found when teachers were given time within the school day to support professional community learning. In schools where time was provided only after school hours, in a voluntary situation, no one showed up. Without the proper allocation of time and space, communication among the individual, the faculty, and the community breaks down, and there ends the community of learners.

Funding

- Tensions can arise with funding demands because of both internal and external school improvement needs. Thus, it is essential to consider how a

PLC is being "used" by and to meet "other" school initiatives. These situations can threaten school improvement efforts and PLC viability, but are necessary for the funding and function of the PLC (Blase, 1988; Sarason, 1990; Scribner et al., 1999).

- Finally, fees and reimbursement are a major point of dispute and competition at schools when considering time requirements for the participants of the PLC (Scribner et al., 1999). Many teachers were found to be willing but the effort had to be worth their sparse time.

Direct and indirect competition for resources, as those considered above, play a major influencing role in the design, function, ability, and development of PLCs.

The issues and dilemmas described and reviewed above influence the degree to which a PLC can be designed and achieved. "These issues form a serious dilemma when they surface as impediments reflecting school cultures that are incongruent with profession communities" (Scribner et al., 1999, p. 154). Therefore, schools wishing to utilize PLCs will be faced with a tremendous challenge:

> As more and more schools use the metaphor of professional community to guide practice, professionals in those schools will have to negotiate these tensions. Such educators will also need to locate a balance that provides sufficient communal characteristics while attending to bureaucratic imperatives in ways supportive of continuous and reflective professional learning that has the best interests of students in mind. (Scribner et al., 1999, p. 154)

The promises of PLCs are alluring, but the pitfalls must be considered before jumping into the challenging task of designing and fostering a PLC with a school system.

Are PLCs the Answer?

The emerging question of whether the effort of designing and developing a PLC, considering the barriers and possibility of failure, is actually worth the possible potential outcomes, given the current calls for science education and curriculum overhauls. Furthermore, can professional development meet the needs of teachers and bypass the PLC and potential struggles and failure? More traditional forms of professional development, meetings, workshops, and programs have been found to fall short of sustained school change, as indicated below:

> …[Traditional forms] all consisted of short training courses doing little more than raising awareness of issues; follow up activities or coaching was very rare, even though transfer and development of curriculum and instructional skills depends on ongoing peer coaching (Joyce et al., 1999); professional education in the form of longer award-bearing courses was neglected and the quality of school support for continued professional development was very variable. (Stoll et al., 2006, p. 232)

As Keeley (2009) aptly identified, PLCs are more than department meetings and discussion groups: "they are shifts for some teachers who have traditionally viewed professional development as going off and doing their own thing by attending courses, workshops, conferences, and other such events for their own benefit" (para. 5). Keeley explained that traditional forms of professional development have been beneficial to the individual teacher, but the PLC works to the collective benefit of all members of the community by "building a common knowledge base about effective science teaching and learning" (para. 5).

The National Science Teachers Association (NSTA) president, Page Keeley, outlined the potential utilization of PLCs in science in the online NSTA report, *Professional Learning Communities Strive for a Science-Focused Identity* (2009). Keeley referred to the National Commission on Mathematics and Teaching for the 21st Century report, *Before It's Too Late*, which recommended improved professional growth of K-12 teachers as a means of enhancing the quality of science and math education in the United States and the role PLCs could have in this recommendation. Keeley (2009) recognized "the PLC, as a powerful, job-embedded structure…where teachers come together to engage in powerful learning where student success is at the core" (para. 6).

> Like many of my professional development colleagues, [I] strongly believe PLCs can transform teacher practice and move teachers beyond the isolation of individual efforts to collaborating as a team to improve the science learning of all students. The very essence of a PLC is its focus on student learning. Imagine groups of science teachers coming together to identify student-learning needs in science and then mapping out a strategy to learn more about how they can address these needs collectively…. With the current focus on improving STEM education, time, resources, and school support for building and maintaining PLCs must be sacrosanct. (Keeley, 2009, para. 6)

Current work and data thus far on science PLCs are limited, but Keeley's NSTA initiative is the headliner of science and PLC work.

Professional learning communities (PLCs) show tremendous potential for enhancing student learning via a supportive and collaborative community of teachers both in general and specifically in science education.

> The professional learning community model is a grand design—a powerful new way of working together that profoundly affects the practices of schooling. But initiating and sustaining the concept requires hard work. It requires the school staff to focus on learning rather than teaching, work collaboratively on matters related to learning, and hold itself accountable for the kind of results that fuel continual improvement. (DuFour, 2004, p. 11)

Empirical evidence and research suggest that PLC schools produce higher student achievement more equitably than their conventional counterparts (Atkinson et al., 2009; Williams et al., 2008). The consensus is that the design and development of PLCs are worth the effort because of the potential outcomes and support a PLC offers teachers and school change efforts over sustainable periods of time. As Stoll et al. (2006) concluded, "it also demonstrates that PLCs appear to be worth the considerable effort put into creating and developing them, although there is still much more to learn about sustainability" (p. 247).

Needed Research

The need and call for science curriculum reform are undeniable. The historic trend of science curriculum reform has been a top-down method, a trend being sustained and nourished by the *Framework for K-12 Science Education* and *Next Generation Science Standards* (NGSS). There is an irrefutable need for science teachers and school departments to develop strategies to deal with reform efforts, support positive curriculum changes, and provide a means for teachers to respond appropriately to mandated curriculum/ pedagogical changes. Teachers need to maintain their role within the curriculum development process (bottom-up development) in order to ensure that curriculum changes enforced are meaningful to students (proximal) and sustainable. As Darling-Hammond (1997) discussed, “studies of change efforts have found that the fate of new programs and ideas rests on teachers’ and administrators’ opportunities to learn, experiment, and adapt ideas to their local context” (p. 214). The contention of this research is to identify whether manipulating the PLC model to that of a science PLC could be the means to support or undermine the teacher’s opportunity to work collectively towards science curriculum changes that best serve the student population, department, and school goals.

Lacking within the literature are the role and process of science teachers and departments in mediating curriculum to address science change movements and reform. Lacking as well is research on the means to support science teachers, departments, and schools throughout the complex and multifaceted task of science curriculum changes. Research is needed that works at enlightening questions about the possible role PLCs can play in science reform, school-based science curriculum changes, and department or subject-specific reform efforts. Also needed is research on the role PLCs can play in supporting or undermining bottom-up curriculum development and proximal pedagogy by teachers. Finally, research is essential on the role of PLCs in bottom-up science curriculum development in light of the new *Framework* and NGSS, considering that many stakeholders are involved in developing a proximal science curriculum. Because the amalgamation of PLCs, school-based curriculum change, and science is unexplored, the data collected from this study will work towards informing PLC literature of a science PLC application to school-based science curriculum change.

CHAPTER 3: METHODOLOGY

Methods

This research studied a specifically bounded case and the data collected were qualitative and deepened by quantitative analysis. The mixed methods case study combined data sources in the search for a deep understanding of the development, role, and influences a science PLC had on a science department's goals for school-based science curriculum change. The researcher was the primary instrument of data collection and analysis. The researcher was as well an active participant in the science teacher PLC. Meeting protocols, observation protocols, surveys, and reflection questions were therefore designed to ensure the separation of researcher participation and data collection. In addition, all data collection, observations, and research interpretations included detailed descriptions and explanations to provide the reader with transparency. "The basic generation of meaning is always social, arising in and out of interaction with a human community. The process of qualitative research is largely inductive, with the inquirer generating meaning from that data collected in the field" (Creswell, 2009, p. 9). Although this research study was not larger inductive as set coding was applied, deep and rich description of the inductive researcher observations and interpretations was meant to account for the researcher generated meaning that came from participation in the field PLC research.

The mixed model approach was chosen in the recognition that all methods have limitations, and by implementing triangulation of data sources, convergences across qualitative and quantitative data would reinforce and inform both types of data collected (Creswell, 2009), thus allowing for expansion of inferences and emerging themes. In considering the PLC as the case bounded by subject, participants, place, and time (as defined by Merriam, 2009) with a specified goal and lens of school-based science curriculum change, the researcher utilized a transformative mixed method approach with concurrent data collection procedures (Creswell, 2009) and four phases of data analysis: *Phase 1: Qualitative Data Analysis; Phase 2: Quantitative Data Analysis; Phase 3: Mixing and Identification of Emerging Themes;* and *Phase 4: Secondary Analysis of Individual Codes.*

Study Participants

The study took place at a suburban, public middle school containing grades 6-8. The middle school had between 1,000-1,200 students per year and over 100 employees and staff members. The science department consisted of 12 middle school science teachers. All science teachers were state certified with science master's degrees or higher. The science teacher participants ranged in experience levels from novice teachers (1 year experience) to seasoned teachers (25+ years experience). The majority of the teachers had not previously participated in a PLC. In Autumn 2011, 11 volunteers from the science department committed to the PLC research and study. Participants were asked to attend to and complete pre- and post-surveys, open-ended reflection questions, and audio-taped PLC meetings. All science department PLC meetings were held within the school building after the school day had been completed. Once the PLC had been established (between the months of September and December), five science PLC meetings ranging between 1-2 hours in length were conducted over five months (January-May) in PLC year 1 (2011-2012) and three science PLC meetings were conducted in PLC year 2 (2012-2013) over the same five months (January-May) with participation of the same cohort of teachers both years. The cohort of science department teachers continued work on the science curriculum change goals outlined in the PLC, during the summer vacation. Summer work was completed after PLC 1 during the summer of 2012 and after PLC 2 during the summer of 2013.

Study Setting

The study setting constituted a high-income area suburban public middle school. This high-income school maintained community requirements of quality education as reflected by their expectations of high standardized test scores across all grade levels and subjects, high state school ratings, high levels of student learning outcomes that supported and reinforced 21st century student skills, high levels of advanced course preparation and participation, above average SAT scores, and high rates of school graduate acceptances to highly rated colleges. As well, this study was taking place at a time when the educational community was faced with increased levels of teacher accountability aligned to state testing and assessments, the addition of the new common core state standards, and the Next Generation Science Standards. These considerations of the new directions of education occurring at the national and state level begin to set the study setting stage for the participants of the science department PLC.

Constituting and Maintaining the Science PLC

As both a researcher and the founding teacher of the science PLC, I was attentive to the need to maintain the PLC as separate from my related research efforts. The following steps therefore describe the plan I utilized to maintain research rigor and address the separation of being both researcher and science teacher PLC participant.

1. The science PLC design and hypothesized function was presented to the identified school and science department to distinguish interest and whether a recognized value of a science based PLC was visible to the science teachers and departmental goals. With indentified interest, Institutional Review Board (IRB) approval for the research study was obtained.
2. Upon departmental approval, I (as researcher) along with the science administrator and any willing science teachers participated in PLC training: online courses; webinars; PLC workbooks; and PLC research data (Solution Tree, 2012) in preparation for setting up and running the PLC. As well, the science administrator and I (as researcher) worked collaboratively to outline the structural resources required for the PLC to function (time, materials, personnel, space, and funding) prior to the initiation of the science PLC.
3. Once prepared and with the final approval from the superintendent of schools and middle school principal, the designed science department PLC model was again presented to the science department for reflection, input, and approval. At that time, the IRB consent forms were obtained from the science department for participation in the science PLC. The teacher cohort then completed the pre-Likert Scale survey and open-ended reflection questions.

The department's input was incorporated into the infrastructure of the science PLC and the first meeting was scheduled.

4. Using the department's pre-meeting reflection responses, PLC meeting topics were initially outlined by the facilitator (myself as researcher) and the science administrator. The topics were then presented to the department for final approval and changes prior to the first meeting. Collective science department dialogue led to the science PLC final meeting topic outline, chosen as most useful to the members in their goals of curriculum change. PLC meetings and topics are presented in Table 1.

Table 1

Science PLC 1 and PLC 2 Meetings, Topics, and Presenters

PLC Meeting Number	**PLC Meeting Topic**
PLC 1.1	Current Trends in Science Curriculum and Our Vision for Science Changes (Professor of Science Education presentation)
PLC 1.2	Science Curriculum in Local School Districts – Trends and Comparison (School district science department presentations)
PLC 1.3	Science Curriculum Scope and Sequence Grade 8 (Grade 8 teacher presentation)
PLC 1.4	Science Curriculum Scope and Sequence Grade 7 (Grade 7 teacher presentation)
PLC 1.5	Science Curriculum Scope and Sequence Grade 6 (Grade 6 teacher presentation) and Changes to Our Curriculums (first steps)
Summer 2012 Curriculum Work	Continue outlined and desired science curriculum changes to be implemented the following school year
PLC 2.1	Continuing the Momentum – Review Vision and Science Curriculum Change Plans
(Interim month)	Time for alignment, implementation and reflection
PLC 2.2	Alignment to the New K-12 Science Framework
(Interim month)	Time for alignment, implementation and reflection
PLC 2.3	Alignment to the Next Generation Science Standards – Next Steps
Summer 2014 Curriculum Work	Continue development, refinement, and designing science curriculum changes to be implemented the following school year

Note. Science department PLC curriculum work was continued over the summer, although this was not considered an official PLC meeting, as the department did not meet as a whole group until the following school year.

5. Topic discussions fluidly led into the identification of the science department's PLC views and vision. The science department PLC participants were asked to define their PLC vision statement clearly. The vision statement was refined throughout the PLC meetings but represented the core science community goals and participants' united purpose. The vision was reviewed at the beginning of every PLC meeting.
6. Once the science PLC meetings began, each science PLC meeting followed the PLC meeting protocol (Table 3). The researcher facilitated the science PLC meetings, although the meeting leaders varied in accordance with the PLC meeting topics and focus. As well, it was suggested by the science administrator that the science PLC meetings utilize the *Tuning Protocol* (Blythe, Allen, & Powell, 2007) to foster critical analysis and reflection by participants during the meetings (Appendix A). The *Tuning Protocol* was a process originally designed to analyze lesson plans and was in this case, structured to provide for reflection and meaningful feedback for any presented department work, not just lesson plans. As outlined by the *Tuning Protocol,* presenter(s) first introduced and described their work, and then presenter(s) focused the group's reflection by asking participants to consider a particular lens, aspects, or question. After asking clarifying questions the *Tuning Protocol* required participants to offer the presenter(s) three levels of reflective feedback and analysis: warm (identified positive/successes), cool (possible improvements/considerations for change), and critical (deeper questions on purpose, appropriateness, structure, and big picture

considerations). The *Tuning Protocol* was guided by a practiced facilitator within the science department:

> The protocol enables reflection for change as new ideas and questions are added to the process and content. A common language is created when participants start to trust each other's knowledge, expertise and questions. This tool can be useful in the beginning, middle and end of any process or project, and will move the work deeper at any point. (Allen & McDonald, 2003, p. 1)

7. Each meeting was audio-taped (for transcription and coding) and the researcher/participant took detailed field notes according to the observation protocol (Appendix B1, B:2). Reflection questions were given to participants at the end of each meeting and collected for the purpose of informing the researcher of emerging themes. After the final PLC meeting, the post-Likert survey was given to all participants.

Research Design

The research used a mixed model design combining both quantitative and qualitative approaches in the study method, data collection, and analysis (Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 1998, 2003). According to Onwuegbuzie and Johnson (2006), the fundamental principle of mixed methods research calls for combining quantitative and qualitative approaches that have complementary strengths and non-overlapping weaknesses (Brewer & Hunter, 1989; Johnson & Turner, 2003). By "complementary strengths," Onwuegbuzie and Johnson are implying the combination of different methods and strategies in multiple and creative ways. Onwuegbuzie and Johnson outlined the fundamental conditions of a concurrent mixed method research design, which were utilized to guide the structure of the research design and data collection and analysis: both the quantitative and qualitative data were collected separately at approximately the same point in time throughout the PLC; after the collection and interpretation of data from the quantitative and qualitative components, a meta-inference was drawn which mixed or integrated the inferences made from the separate quantitative and qualitative data and findings.

Data Collection

The data collected throughout the research were comprised of detailed researcher field notes and observations (Appendix B:1, B:2), audio-taped and transcribed PLC meetings, the PLC meeting Likert scale surveys (Appendix C:1, C:2), the pre- and post Likert survey tilted the Professional Learning Community Assessment-Revised or PLCA-R (Appendix D), open-ended reflection questions (Appendix E), and all artifacts resulting from the PLC meetings (emails, correspondence, handouts, presentations, etc.). To provide for qualitative reliability, as suggested by Yin (2003), the researcher used an observation protocol, as outlined by the Collaborative Evaluation Led by Local Educators (Brackett & Hurley, 2004), for PLC meeting field notes. The Likert-scaled surveys and open-ended reflection questions were designed by Iowa State University's Best Practice in Learning Community Assessment (1995-2012) and to maintain consistent instrumentation the same surveys and questions were used throughout PLC 1 and PLC 2. As well, the PLCA-R was used to collect Pre- and Post-PLC data. All PLC meetings were audio-recorded, and as Gibbs (2007) suggests, the transcription process was carefully reviewed, and set coding using the five essential dimensions of PLCs was consistently compared to the data, allowing for emerging themes. Data collected included pre-determined codes, emerging results, open- and close-ended questions, and multiple data sources (meetings, reflections, discussions, surveys, interactions, written responses, audio-transcripts, field notes and observations, artifacts, etc.). The variant data sources allowed for triangulation and a deep description of the science department's undergoing school-based curriculum change using a PLC model.

Each piece of data collected was meant to inform a particular research question to offer both qualitative and quantitative insight to the research. Table 2 outlines the connection between the research questions and collected data.

Table 2

Connection Between Research Questions and Data Collected

Research Questions	**Data Collected**
1. How did the five dimensions of successful PLCs manifest and evolve as the science PLC progressed?	- Audio-taped PLC meetings (protocol employed) and discussion transcripts - Field notes (protocol employed) - PLCA-R - Pre-assessment and post-assessment Likert scale
2. What were the actions and outcomes of a PLC focused specifically on a science department?	- Audio-taped PLC meetings (protocol employed) and discussion transcripts - Field notes (protocol employed) - Reflection questions (open-ended)

Table 2 continued

Research Questions	Data Collected
3. How did the actions of the science PLC facilitate or impede the science department's goals of school-based science curriculum change?	- PLC meetings (protocol employed) and discussion transcripts - Field notes (protocol employed) - Identification of vision (pre and post) - Pre- and post-Likert Assessment - Reflection questions - Artifacts related to PLC meetings - Pre-assessment and post-assessment open-ended reflection responses - Science curriculum scope and sequence - Science pedagogy work - Science curriculum work
4. What external and internal factors facilitated or inhibited the functions of the science PLC and science curriculum change goals?	- Audio-taped PLC meetings (protocol employed) and discussion transcripts - Field notes (protocol employed) - PLCA-R

Note. Single datum was used for multiple research questions, as it was individually analyzed for the aspects of the different research questions.

Instruments

Pre-/Post-Likert scale survey. The Professional Learning Community Assessment-Revised or PLCA-R (Appendix D) utilized a 4-point Likert scale for analysis. The scale worked as follows: *(1) Strongly Disagree, (2) Disagree, (3) Agree,* and *(4) Strongly Agree.* As a 4-point Likert scale does not allow for a neutral participant response, the neutral mean utilized by the research is an estimate based on the 4-point scale. The estimated neutral mean was 2.5, the mid-point on PLCA-R Likert scale. Due to the statistical reliability and validity of the instrument, the PLCA-R was used to assess the progression of the PLC. The PLCA-R is a diagnostic tool, which has been utilized to identify practices that enhance and evaluate Professional Learning Communities in schools (Oliver, Hipp, & Huffman, 2003). The PLCA-R gauges the perceptions of staff regarding research-identified essential dimensions to successful and effective PLCs: shared and supportive leadership, shared values and vision, collective learning and application, shared practice, and supportive conditions.

> The measure has been administered to professional staff in numerous school districts at varying grade levels throughout the U.S.…providing the opportunity to review the dimensions for internal consistency. Initial and subsequent studies have provided ongoing validation of this diagnostic tool. (Oliver, 2009, p. 5)

The most recent analysis of PLCA-R (Oliver, 2009) resulted in Cronbach Alpha reliability coefficients for factored subscales (N = 1209) as follows: Shared and Supportive Leadership (.94), Shared Values and Vision (.92), Collective Learning and Application (.91), Shared Personal Practice (.87), Supportive Conditions-Relationships (.82), Supportive Conditions-Structures (.88), and a one-factor solution (.97).

> The PLCA-R is available for dissemination and use by educators and others as an assessment tool that measures practices observed at the school level relating to the critical attributes within professional learning community dimensions.… Testing and retesting…find it useful as a measuring tool to assess perceptions based on the dimensions of a PLC. (Oliver, Hipp, & Huffman, 2003, p. 9)

PLC meeting protocol. The PLC meeting protocol was designed to facilitate the PLC's efficient use of meeting time, as suggested by Kovach's (2012) teacher leadership resource tool and planning protocol. As noted earlier, the PLC meetings lasted between 1-2 hours after school within the school building. It was important to run meetings efficiently to respect participants' time, address the goals of the PLC, progress towards PLC desired outcomes, and allow time for participant reflection. In aligning with the purpose of a PLC, the protocol was designed to allow for community participation and consensus while promoting equal voice, collaborative decision-making and feedback, reflection time, and collaborative outlines for future PLC meeting agendas. The general skeleton of the PLC meeting protocol is outlined in Table 3 and contains make-up of the introduction, meeting body and closure.

Table 3

Science PLC Meeting Protocol Outline

PLC Meeting Overview	**Introduction (15-20 min)**	**Body (45-75 min)**	**Closure (15-20 min)**
PLC Meeting # (___) Date: _____________ Topic: ____________ _________________ _________________ _________________ _________________ Goals: ___________ _________________ _________________ _________________ _________________ _________________ _________________	- Review PLC vision statement and reflect on progress - Reflection on previous meeting - Review current meeting outline - Brainstorm and share in 3 minutes (individually or with group) the focus during today's meeting (topic)	*Tuning Protocol* - PLC leader presentation (no feedback from group at this time) - Clarification questions - Group brainstorming and share of cool and warm feedback - Individual reflections (3 minutes each) - PLC leader reflections and comments - Use information towards PLC vision statement - Connections to grade-level science curriculum	- Individual reflection - Open discussion on school-based science curriculum change - Outline for next meeting - Review PLC vision statement and reflect on progress

Note. Adapted from Kovach (2012)

PLC meeting audio-tapes and transcription. The PLC meetings were audio-taped and transcribed for detailed analysis and coding. Recording procedures, as outlined by Creswell (2007) and Merriam (2009), were employed to provide for qualitative reliability. "This practice ensures that everything said is preserved for analysis" (Merriam, 2009, p. 109). As suggested by Merriam (2009), a small digital recorder was used to audio-tape the meeting; "...respondents tend to forget they are being taped, especially if one uses an unobtrusive digital recorder" (p. 109). However, all participants were made aware of the recording procedures prior to the meetings. To protect the confidentiality of all subjects, only those who consented to being recorded were involved in the meetings ($N = 10$). The consent forms clearly stated audio-taping information and initialing that section indicated the participants' comprehension and consent (Appendix F). In transcripts and field notes, no names were used, only pseudonyms representations to protect anonymity and confidentiality. Transcribed meetings were used to deepen the understanding and discussion of the progression of the science department's PLC through school-based science curriculum change efforts.

Field note/observation protocol. To provide for qualitative reliability during field observations of the PLC meeting procedures, as suggested by Yin (2003), the researcher used observation protocols. The protocols were chosen from Sawada et al. (2000) and Bracket and Hurley (2004) and aligned with Merriam's (2009) outline of essential elements to be observed in the field: physical setting, participants, activities and interactions, conversations, subtle factors, and observer behavior. The use of the various protocols covered a larger range of researcher observations and input, offering interpretive details not available in a single protocol. As well, the protocols allowed for in-depth descriptions and researcher reflections (Merriam, 2009). In particular, Sawada et al.'s (2000) Reforming Teacher Observation Protocol or RTOP (Appendix B:1) was used along with Bracket and Hurley's (2004) Collaborative Evaluation (Appendix B:2) to enhance reliability and data collection procedures in the field.

Open-ended reflection questions. The open-ended reflection questions were meant to further inform and deepen the emerging results and progression of the PLC. According to Merriam (2009) the reflection questions (confidential and cleared of identifiers) were included because "personal documents are a reliable source of data concerning a person's attitudes, beliefs, and view of the world…they reflect the participant's perspective" (p. 143). Merriam also pointed out that wording is a crucial consideration in extracting the desired information from participants. Therefore, the open-ended questions (Appendix E) used in this research were previously designed, used, and tested by the Iowa State University (ISU) Learning Communities Assessment (Cook, Huba, & Epperson, 2001; Epperson, Huba, & McFadden, 2001) and are available online. Analysis of the *ISU Learning Community Survey* (Epperson, Huba, & McFadden, 2001) found the following for items comprising knowledge and ability scales and scale reliabilities ($N = 1692$): oral communication/leadership ($r = .88$), time management ($r = .88$), teamwork ($r = .82$), written communication ($r = .84$), critical thinking/problem solving ($r = .82$), knowledge ($r = .73$), and diversity ($r = .73$). Therefore, the questions worked to ask participants in a clear and reliable way to share information and reflection on the learning community, its benefits, and possible improvements.

Data Analysis

Analysis Introduction and Overview

The process of data analysis, particularly in this concurrent mixed methods research, involved the meticulous outlining of the qualitative and quantitative data analysis methods performed. Importantly, the plan utilized to merge the two types of analyzed data sets must be explicit to ensure that inferences and patterns from collected data inform and deepen the emerging themes and interpretations. The mixed methods approach coalesced various data sources for inference triangulation, development, and expansion throughout the data sources and across the research study. Therefore, I employed four phases of data analysis to ensure rigor, reliability, and validity.

During *Phase 1: Qualitative Data Analysis*, the recorded and transcribed science PLC meetings and open-ended reflection questions were investigated using the set codes of the five dimensions of PLCs for the purpose of descriptive, analytical, and graphical analysis. Both positive and negative instances of the code scheme were identified to reinforce descriptive and emerging themes present or not present in the data. In *Phase 2: Quantitative Data Analysis*, the Likert-scale data, pre-PLC surveys and post-PLC surveys chosen are verified diagnostic tools that address the same five dimensions as the code dimensions utilized in *Phase 1*. The individual dimension results from the quantitative data were displayed in graphical representations for interpretation of patterns of dimension development across the PLC experience. In *Phase 3: Mixing and Identification of Emerging Themes*, the patterns and inferences from the qualitative and quantitative phases were aligned through triangulation, compared, and interpreted to provide elaboration of the merging themes within the data sets. A constructed matrix was used to display the aligned qualitative and quantitative data indicating how each was used to inform the other. The final analysis stage, *Phase 4: Secondary Analysis of Individual Codes*, involved a secondary analysis of the individual coded data for a deeper interpretation and to answer research questions 2, 3, and 4. Figure 2, as suggested by Cotos (2011), is offered to clarify and visually display the concurrent mixed methods data analysis design and phases in this research study, which occurred under the umbrella of using a PLC model for a science department involved in science curriculum change efforts.

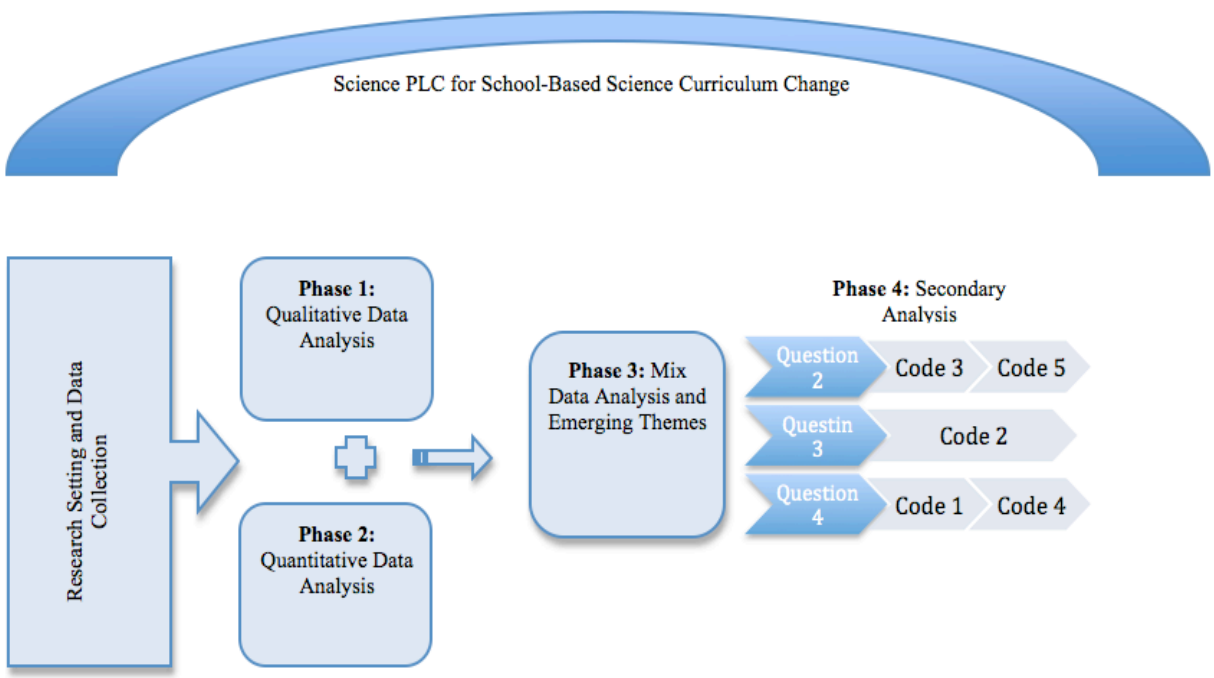


Figure 2. Concurrent Transformative Mixed Methods Design Applied to a Science PLC for School-based Science Curriculum Change (Adapted from Cotos, 2011, p. 427)

It is recognized that in mixed methods research, "validity stems more from the appropriateness, thoroughness, and effectiveness with which those methods are applied and the care given to thoughtful weighing of the evidence" (Bazeley, 2004, p. 148).

Therefore, in the sections below I provide a rich and thick detailed account of the four data analysis phases (Creswell, 2009), allowing the reader to interpret the context and credibility of the researcher's experience, conclusions, and result implications.

Phase 1: The Qualitative Data Analysis

Data analysis and coding was managed using the mixed methods data analysis software tool Dedoose (2010). The qualitative data was represented by the open-ended reflection questions collected after each PLC; the researcher's field notes collected via the observation protocol, and the transcribed PLC meetings analyzed using Creswell's (2009) suggestions for reviewing all data, coding, identifying themes, and interpreting inferences and results. Figure 3 details of each step of the qualitative analysis process.

The five qualitative coded dimensions are described in detail below. Each coded dimension description is summative, illustrating the types of data (types of actions, decisions, comments, dialogue, etc.) that were defined as representing each of the five dimension categories. As well, I coded the data for negative instances of dimension descriptions. Negative instances were cases directly contrary to outlined dimension descriptions. In this sense, data sets were truly coded for 10 set code dimensions: the 5 positive characteristic examples of the coded dimensions and the 5 negative characteristic examples of the coded dimensions. Appendix G:1 presents the full elaboration of the code dimension descriptors that were initially used to define and arrange the dimension characteristics. Appendix G:2 identifies the specific distinguishing dimension characteristics for each of the coded dimensions. Found within Appendix G:3 is the reduced positive and negative distinguishing characteristics for each coded dimension, resulting in the PLC coded dimension rubric used to code the qualitative data.

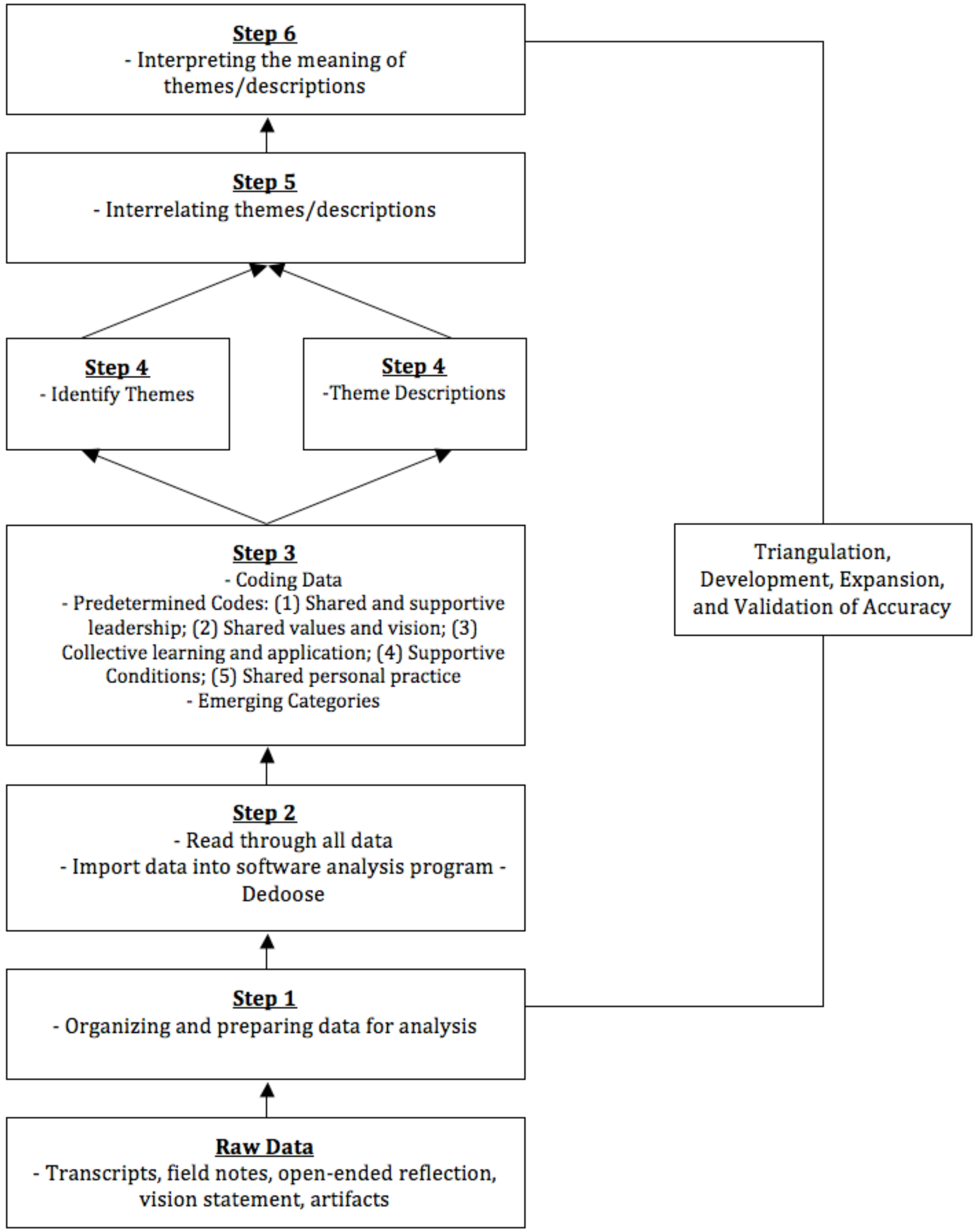


Figure 3. Qualitative Data Analysis Steps (Adapted from Creswell, 2009, p. 185)

All code descriptions and aspects were research-based (DuFour et al., 2005; Giles & Hargreaves, 2006; Oliver, Hipp, & Huffman, 2003; Hord, 2009; Scribner et al., 1999; Stoll et al., 2006). The five code dimensions are as well, identical to the five Likert scale dimensions aligned to the PLCA-R and PLC Likert-scale surveys. The coded dimensions were set with descriptors using the software data analysis tool Dedoose (2010).

Code (1) Shared and Supportive Leadership Dimension. Educational and school reform literature (DuFour, et al., 2005; Hord & Sommers, 2008; Huffman & Hipp, 2003) collectively recognizes the essential role of effective leadership to initiating and sustaining school improvement efforts. Leadership is critical to creating, guiding, and supporting successful reform and school change. Within the PLC, the traditional leadership role is instead a collective effort shared by the members of the PLC. In a shared leadership model, administrators, experts, and teachers work together to critically analyze problems, improvements, and possible solutions. In shared and supportive leadership situations, the administration is successful at distributing authority; teachers are an essential part of the decision-making process aiding in critical analysis; and the learning community together questions, investigates, and seeks solutions for school improvement. Shared and supportive leadership occurs when the traditional role of the administrator is broken down and redistributed to the learning community, as seen through collaborative dialogue and the shared responsibility of decision-making. The following list describes some of the distinguishing characteristics used to identify Dimension (1).

<u>Positive Shared and Supportive Leadership</u>

- Science administrators share important information with teachers.

- Collaborative dialogue results from administrators seeking advice, counsel, and critical analysis from teachers on specific topics or questions.
- Statements are made that the resulting decisions from the discussion will be brought back to be implemented by science administrators.

<u>Negative Shared and Support Leadership</u>

- Staff members indicate they are unaware and not involved in departmental issues and decisions.
- Staff members are told of decisions that have been made.
- Science administrators hold the majority of leadership, power, and authority throughout a discussion or whole meeting.

Code (2) Shared Values and Vision Dimension. The foundation of a successful PLC is one built on a steadfast vision of continual improvement of student learning and achievement. The vision is derived from the values of the individual teacher's beliefs about teaching and learning. The PLC engages individual and group values through reflection and discussion and works to develop a communal commitment to improved student learning through the development of a vision statement. This devotion to improved student learning is the foundation of all PLC decisions, discussions, and efforts to focus on changes for the common goal of higher student achievement. It is the learning communities' values that create the norms (Little, 1997) of a self-aware, self-critical, and effective PLC that utilizes committed members to strive to reach the PLC vision. Vision is then the driving force behind the PLC's purpose and function; it guides all decision making about teaching and leaning (Fullan, 2007; Hord, 2004; Pankake & Moller, 2003;

Senge et al., 2000). The following list describes some of the distinguishing characteristics used to identify Dimension (2).

Positive Shared Values and Vision

- The vision for improvement in science education is discussed by PLC members.
- The vision is revisited and revised based on a shared consensus of PLC members' values.
- Discussion of vision is focused on improved students, teaching, and learning in science.

Negative Shared Values and Vision

- Staff members indicate they are not aware of a unified departmental vision.
- Staff members indicate they are not making decisions according to the department vision (but for other reasons?).
- Individual staff members indicate that their own visions of science do not align with departmental vision.

Code (3) Collective Learning and Application Dimension. The PLC functions to encourage its members to collectively seek new knowledge and information as well as ways of applying that knowledge to teaching and learning. The PLC members work collaboratively by sharing information and developing strategies to reinforce the PLC vision. Together through collective dialogue, the members generate solutions reinforcing their commitment to the vision of the PLC. Reflective dialogue and inquiry are a result of collective learning (DuFour, Eaker, & DuFour, 2005; Huffman & Hipp, 2003). The application of PLC collective learning comes in the form of the curriculum, pedagogy, assessments, and development of school and staff values and culture. High standards, pedagogy reflective of current teaching and learning research, and student engagement in real, relevant, and connected curriculum are the applied results of the collective learning experienced by the PLC. The following list describes some of the distinguishing characteristics used to identify Dimension (3).

Positive Collective Learning and Application

- The majority of the members participate in discussion of school teaching and learning issues/concerns.
- Members indicate whether they are making plans for curriculum, pedagogy, and assessment to address discussed changes in teaching and learning.
- Members assess, discuss, or reflect on changes implemented as a result of PLC discussions.

Negative Collective Learning and Application

- Staff members refrain from engaging and participating in discussions of teaching and learning issues and concerns.
- Members do not work together nor do they make plans to work together outside of the PLC to change curriculum, pedagogy, and assessments to address improvements.

Code (4) Shared Personal Practice Dimension. As the members of the learning community work together throughout the PLC, they share teaching and learning practices, work together to make and finding meaning, analyze and discuss instructional strategies to meet student needs, and use data to inform their teaching and learning decisions. It is through this process that teachers will participate in debates, discussion, and disagreement while maintaining commitment to the PLC vision. According to Huffman and Hipp (2003), shared personal practice may come in the form of work, curriculum, lessons, activities, assessments, among others, which are shared with the PLC to offer knowledge, skills, and development. It may also be in the form of feedback to enhance pedagogical practices or shared outcomes of instructional practices, or even in form of coaching or mentoring. The sharing of practice occurs when teachers work together to plan, reflect, refine, and assess curriculum and instructional strategies used to work towards enhancing student-learning outcomes. Often, the use of a protocol or structured reflection is implemented to aid shared personal practice and to give teachers the time to identify best practices and skills. The following list describes some of the distinguishing characteristics used to identify Dimension (4).

<u>Positive Shared Personal Practice</u>

- Members share lessons, activities, curriculum, and pedagogy.
- Members share and provide feedback about each other's teaching and learning.
- Members offer to engage in mentoring or coaching outside of the PLC to improve teaching and learning.

<u>Negative Shared Personal Practice</u>

- Members do not take opportunities to share examples of lessons, activities, curriculum, and pedagogy (formally or informally).
- No members provide feedback or reflection regarding each other's teaching and learning for the purpose of improvement.

- Coaching or mentoring opportunities outside the PLC are not offered or discussed.

Code (5) Supportive Conditions Dimension. Certain fundamental supportive conditions are necessary to support the community of learners within the PLC, which are both physical and interpersonal. Therefore, creating supportive conditions includes fostering a collaborative environment through both structural conditions and PLC member relationships (Huffman & Hipp, 2003). Structural conditions are examples of resources (time, money, materials, and people), facilities, and communication procedures. Supportive structural conditions are those where time and space are provided to teachers to learn and develop pedagogy with communication norms to aid in the sharing of information and discussion (Halverson, Grigg, Prichett, & Thomas, 2007). Structural conditions are reflective of the positive use of time, communication procedures, proximity of teachers, size of PLC, and professional development. PLC member relationships include positive and caring relationships, respect and trust, recognition, risk-taking, and devotion of the members to change improvements. Supportive relationships are demonstrated via positive and encouraging dialogues and reflections that nurture collegiality and the PLC vision (Rigsby, 2008). PLC member relationships that reflect the support condition are displayed via positive educator attitudes, widely shared and supported vision and PLC purpose, norms of critical analysis and inquiry, respect, trust, and positive caring relationships. The following list describes some of the distinguishing characteristics used to identify Dimension (5).

<u>Positive Supportive Conditions (Relationships)</u>

- Protocols and strategies are used to encourage member communication and positive interaction and feedback.
- Both positive and negative feedback are shared (indicating trust in the group).
- Supportive relationships are displayed through comments of recognition and encouragement.

Negative Supportive Conditions (Relationships)

- Lack of trust and respect between members is indicated by only negative or demeaning responses or the lack of sensitivity for feelings.
- Members exhibit a refusal of change improvements and suggestions in science.
- The acknowledgment, recognition, and encouragement of others' achievements are lacking.

Positive Supportive Conditions (Structural)

- The PLC meeting structure allots time for teachers to work and share information on teaching and learning improvements.
- Appropriate site and facility are provided to encourage proximity and interaction of PLC.
- Appropriate resources (funding, people, communication) are made available to aid PLC collaboration.

Negative Supportive Conditions (Structural)

- Members complain of "time" as an impediment to working together within or outside the PLC on teaching and learning improvements.
- Space or facility design discourages members from collaboration.

- Needed/desired resources are lacking (funding, people, communication systems).

Examples of each positive code (the five dimensions of PLCs) found within the initial transcript idea units, based on the distinguishing characteristics outlined above, are summarized in Table 4.

Table 4

Examples of Coded Dimensions from PLC Transcripts (2011 – 2012)

Coded Dimensions	**Transcript Examples**
Dimension 1: Shared and Supportive Leadership	*Admin:* If we look at each grade level to tweak at this point, that's something that I would like to do. Maybe each meeting we focus on a grade level, because I know sometimes we're so married to what we're doing that we need an outside perspective, outside from within, just to say "Why do you spend so much time on this?" or "If you're doing this, wouldn't it make more sense to talk about?" or "Maybe force and motion isn't the right thing to use?" I wouldn't take it as somebody from another grade level coming in and telling me what to do but as just another perspective. *Teacher A*: We teachers are more like, attuned to each other and topics and ways of teaching rather than... *Admin:* Yeah…rather than just the administrative/evaluative perspective. *Admin:* I just want to brainstorm how we think the best way to do this is. I am not quite sure whether handing out all three and having each person explain it is best, or whether going one person at a time is best. Does the group have any procedure suggestions…
Dimension 2: Shared Values and Vision	*Teacher B*: We're all willing to look at this and say what can we do to make this better, better not necessarily for us as teachers, but yes for us as teachers, but firstly for the kids. *Teacher G*: I'm willing to change whatever in order to support or to foster to do whatever we need to do in order to get them [students] to have good wait, excellent experiences in learning. *Teacher H*: It [science program] would be to best serve our students and our science curriculum to really support changes or tweaks that work to bring our kids towards science literacy and critical

Table 4 continued

Coded Dimensions	Transcript Examples
	creative thinking, you know those 21st century skills. But then there's this mix of all this other stuff in there and it's a struggle; and we don't want to make another mistake that we have to change in another five years, because that's what we've seen and done historically. We want the best possible curriculum experiences across the grades levels that foster, you know, support science excitement with those smiling faces, growth so they are prepared for the next grade level, and performance on our assessments and the states.
Dimension 3: Collective Learning and Application	*Teacher I:* This is exactly the issue we found in the eighth grade curriculum and our answer was integration. So I think that the key and go-to point is your clarifying question about how to go about the integration of physics and the ecology. I would say since you're not relying on a physics textbook or unit, I think the key is to break it up even more and not make it a separate unit. Instead take this giant rich ecology unit that you guys have, expand it by putting in the physics. *Teacher D:* Exactly what I was thinking along the lines of for that energy unit, you could use energy to teach alternative energy and connect humans, you have a human interaction with the environment section right, so connect the two. You could do electrical energy in there, solar energy, all the forms of energy as part of how humans interact with their environment. *Teacher J:* I was looking at your flight thing, the physics of flight and then going back and looking at predator prey and competition and stuff. Look at the connections you could make …
Dimension 4: Shared Personal Practice	*Teacher D:* I never for ten years taught chemistry with rocks and minerals and it works way better than teaching rocks and minerals. Way better! *Teacher E:* Yes, way better. *Teacher F:* When you and I first did that, I remember we had a bit of a back and forth, okay so we argued and squabbled about it. How does the periodic table relate to minerals and then as soon as you do it with the kids you're like "Oh, that's how." Teacher D: It was so good. I would never go back. *Teacher A:* I agree with you 100%, but my cool feedback on what we're saying and what they're doing is that the ecology unit seems less lab-based and more project-based. Hopefully they could transition that over to a more lab oriented situation so they could practice these skills and bring up the measurement skills. *Teacher I*: I agree, the metric measurement even especially. No, I

Table 4 continued

Coded Dimensions	Transcript Examples
	agree with you. Projects and labs are very distinct things and it's moving frankly, I know towards the higher levels, we need the labs. *Teacher H:* Right. *Teacher B:* I've seen the projects around the school. They're hanging up their beautiful projects, but you're right. *Teacher C:* Ultimately that's what science is. Science is labs investigations and observational investigations.
Dimension 5: Supportive Conditions [Relationships]	*Teacher E:* What I'm hearing is kind of the reason why I wanted to start all of this, for the exact same reasons as the comments. I had concerns about what I was doing compared to other people, and whether it was appropriate. Am I telling things that are a little raw and look a little different too much? Teacher I: But this is how we learn from each other, help each other, and support right? It is the whole point, not easy but look what we did for the sixth grade curriculum. *Teacher C:* What I'm saying is for us to lay out our professional life that takes trust. *Teacher E*: It does! *Teacher G:* It takes trust and in the people that we're putting our words and work out there, because this is our lives work. *Teacher A:* This has been a special kind of thing we have been doing here. *Teacher H:* We of course, have to be sensitive obviously to how we phrase our working, our questions; this supports the function of the protocol.
Dimension 5: Supportive Conditions [Structural]	*Teacher B:* The thing is, when you have department meetings once a month, and there's business to be taken care of, then you also have grade level work that needs to go on for the month-to-month functioning. Who's going to devote the time to have these in-depth conversations? *Teacher D:* You can't take that time. *Teacher B:* That's why they need to do more of what they're offering us, right? Letting us work, collaborate, think, P-L-C. *Teacher E:* Yeah, time to work. It is funny how we work all day and never have any time to actually work. But with this we all together, with the time to discuss what is going on and where we are all going and they have deemed it a worthy discussion, support for what we need. *Teacher B:* We have to keep this up. Next we could just do a period

Table 4 continued

Coded Dimensions	Transcript Examples
	or session with 6-7-8th grade groups. If we alternate that, then that conversation would continue the momentum.

Throughout the process of the analytical coding of the identified idea units, in which "coding comes from interpretation and reflection on meaning" (Richards, 2005, p 94), data coding clusters were formulated. As each data set was coded, data clusters were built upon and combined. Eventually merging of the clusters was used to reveal the emerging concepts informed by all data sets. These concept patterns identified the themes or conceptual elements that spanned the individual examples found within the idea units.

To address the reliability of coding and emerging concepts, a second coder was trained to identify the positive and negative distinguishing characteristics of each of the five set coded dimensions within the idea units. The process of the second coder demonstrated inter-rater reliability by confirming consistency between the coders regarding the outlined and defined set coded dimension distinguishing characteristics.

Inter-rater reliability. To identify whether the positive and negative coded dimension characteristics were transparent in the designated descriptors, transcripts from PLC 1 and PLC 2 were additionally coded by a second rater trained to use the code descriptor rubric (Appendix G:3). The code agreement between the researcher and the trained rater for the PLC 1 and PLC 2 transcripts were calculated by the software program Dedoose, which employed the Cohen's Kappa coefficient (*k*); the results are displayed in Table 5.

Table 5

Inter-rater Reliability

Raters		Code 1	Code 2	Code 3	Code 4	Code 5
Researcher - Rater 2	N agreed	33	35	25	28	30
	k	.76	.77	.64	.67	.71

The overall code inter-rater calculations were found to be $k = .713$; thus, all coefficients indicated high levels of agreement between the raters as Cohen Kappa values greater than 0.6 are considered strong, because the Cohen Kappa coefficient is a value beyond chance.

Phase 2: Quantitative Data Analysis

The quantitative data were represented by the participant responses to the PLCA-R (Appendix D) Likert scale responses used as the pre- and post PLC surveys; the PLC Meeting Short Survey (Appendix C:1) given after each PLC meeting; and the PLC Mid- and End-year Survey (Appendix C:2) given respectively. Each survey instrument aligned with the five coded dimensions of successful PLCs (this included the positive and negative code schemes of each of the five dimensions). The 4-point Likert-scale responses were interpreted as follows: *(4) Strongly Agree* and *(3) Agree* were considered a positive response for the code dimension; and *(2) Disagree* and *(1) Strongly Disagree* were considered a negative response to the code dimension. As a 4-point Likert scale does not account for a neutral position nor does it allow the participant to choose a neutral response, the estimated mean score of 2.5 was considered the mid-point between agreement and disagreement and tending towards a more neutral position. Notably as a neutral position was not offered to the participants by a 4-point Likert scale survey, the participants were not willing choosing a neutral position. Therefore a mean score ranging from 2.1 – 2.3 was considered a weak response and tending towards disagreement and a mean score ranging from 2.4 – 2.9 was a weak response tending towards agreement.

For each individual code dimension, the mean and standard deviations (Appendix H:1) were calculated and graphically represented to trace the development of the code across the study. Therefore, the graphs for each dimension were a descriptive tool for pattern and trend identification of individual code dimensions. Finally the dimension graphs were aligned and all data were overlapped for the purpose of across-dimension pattern/trend identification and overall interpretation of dimensions throughout the PLC process. To ensure quantitative descriptive test appropriateness and accuracy, detailed description and justification can be found in Appendix H:2.

Phase 3: Mixing and Identifying Themes

After I completed separate analyses of both sets of data types in *Phase 1* and *Phase 2*, emerging themes and patterns were compared and aligned for triangulation and essentially "mixed" for richer descriptive inference interpretation. Triangulation is the term used to describe the bringing together of complementary methods or data sources for the purpose of interpretation. This interpretation phase involved comparing the separate results of each phase to best understand the emerging themes (Borrego, Douglas, & Amelink, 2009; Creswell & Plano Clark, 2007; Morse, 1991). This particular mixed-methods approach, which used a concurrent transformative strategy, was guided by the theory and research of Creswell (2003) and Cotos (2011), respectively. I modeled my transformative mixed method approach on Cotos' (2011) research, which is a recent model of the concurrent transformative mixed methods research in the education field.

Thus by aligning qualitative and quantitative data by common dimensions, I triangulated the data sets to identify patterns and formulate inferences and interpretations within and across individual coded dimensions.

Phase 4: Secondary Analysis of Individual Dimensions

A secondary analysis was preformed for each set of coded data, as each related to a particular research question. The purpose of the secondary analysis was to delve more deeply into each individual dimension, looking to identify specific developments related to research questions 2, 3, and 4. Note that research question 1 was an overall data analysis for all of the coded dimensions (*Phase 1-3)*, whereas the remaining three research questions were aligned specifically with only those coded dimensions meant to inform the specific question. Research question 2 utilized an in-depth analysis of *Code (3) Collective Learning and Application Dimension* and *Code (4) Shared Personal Practice Dimension* to identify the actions and outcomes of a science PLC. Research question 3 used the in-depth analysis of *Code (2) Shared Values and Vision Dimension* to look at the science PLC's actions that facilitate or impede curriculum change goals. Finally, research question 4 required an in-depth look into *Codes (1) Share and Supportive Leadership Dimension* and *(5) Supportive Conditions Dimension* to identify the internal and external factors that positively or negatively influenced the science PLC. Table 6 summarizes the connections between the research questions and informs the in-depth analysis purpose and function as the coded dimensions aligned with the particular research questions.

Table 6

In-depth Coded Dimension Alignment with Research Questions

Research Questions	Data Analysis Dimension Alignment	Data Interpretation
1. How did the five dimensions of successful PLCs manifest and evolve as the science PLC progressed?	Qualitative: ● Set Coding (Predetermined 5 dimensions of PLCs) of: - PLC transcription - Field notes Quantitative: ● Descriptive Analysis of: - Coded data dimension (1)-(5) - PLCA-R interpretation of dimensions (1)-(5) - Pre- and Post-Likert - Assessment interpretation of dimensions (1)-(5)	● Quantification of qualitative data via code descriptive analysis ● Triangulation - alignment of data sources (coded and graphical stats) to support or change emerging themes and explore outliers between dimensions (1)-(5) ● Development, Expansion, and Interpretation of all dimensions (1)-(5)
2. What were the actions and outcomes of a PLC focused specifically on a science department?	Qualitative: ● Set Coded Dimensions: (3) Collective learning and application and (4) Shared Personal Practice - Transcribed PLC Meeting - Research field notes - Reflection questions ● Result Identification within Dimension (3) and (4) ● Result Description (interconnecting results) ● Interconnecting Dimension (3) and (4) Quantitative: ● Quantification of qualitative data via dimension descriptive analysis ● Descriptive and Statistical Analysis of Dimensions (3) and (4) for: - Coded data - PLCA-R Pre- and Post-Likert Assessment	● Quantification of qualitative data for dimensions (3) and (4) ● Triangulation (alignment of data qualitative and quantitative sources of dimensions (3) and (4) to support or change themes) ● Development, Expansion and Interpretation of only dimensions (3) and (4)

Table 6 continued

Research Questions	Data Analysis Dimension Alignment	Data Interpretation
3. How did the actions of the science PLC facilitate or impede the science department's goals of school-based science curriculum change?	Qualitative: ● Set Coded Dimension (2) Shared Values and Vision - Transcribed PLC Meeting - Research field notes - Vision statement - Reflection questions - Artifacts (curriculum and pedagogical work) ● Result Identification within dimension (2) ● Results Description (interconnecting results) Quantitative: ● Quantification of qualitative data via code descriptive analysis ● Descriptive and Statistical Analysis of Dimension (2) for: - Research field notes - PLCA-R - Pre- and Post-Likert Assessment	● Quantification of qualitative data via dimension (2) descriptive analysis ● Triangulation (alignment of data qualitative and quantitative sources of dimension (2) to support or change themes) ● Development, Expansion and Interpretation of only dimension (2)
4. What external and internal factors facilitated or inhibited the functions of the science PLC and science curriculum changes goals?	Qualitative: ● Set Coded Dimensions: (1) Shared and supportive leadership and (5) Supportive conditions for: - Transcribed PLC Meeting - Research field notes - Reflection questions ● Result Identification within dimension (1) and (5) ● Result Description (interconnecting themes) ● Interconnecting dimensions (1) and (5) Quantitative: ● Quantification of qualitative data via code descriptive analysis ● Descriptive and Statistical Analysis of Dimensions (1) and (5) for: - Coded data - PLCA-R - Pre- and Post-Likert Assessment	● Quantification of qualitative data for dimensions (1) and (5) ● Triangulation (alignment of data qualitative and quantitative sources of dimensions (1) and (5) to support or change themes) ● Development, Expansion and Interpretation of only dimensions (1) and (5)

Validity, Reliability, and Ethical Considerations

A researcher must consider all potential threats to validity, then design preemptive means to address those threats in the procedure, to ensure both validity and reliability of inferences made from collected data (Cook & Campbell, 2001; Creswell, 2009; Creswell & Miller, 2000). Threats to the validity of this research must be considered for both qualitative and quantitative methods because of the mixed methods research approach.

Quantitative Considerations

Both internal and external quantitative validity are necessary for consideration. Internal quantitative threats include those parts of the procedure that could threaten the ability to draw inferences from the data (Creswell, 2009). In this case, the main internal threat was “participant mortality,” or the potential for drop out from the PLC. To account for this possibility, PLC recruitment was open to the entire science department in the middle school, thus allowing for a larger sample population. Another internal consideration was “instrumentation” because a change in instrument would impact scores and results. Therefore, the same instrument design for both pre-test and post-test was used. External quantitative threats represented incorrect inferences made from the data collected, the main source of which was “interaction of history and treatment”; that is, because the study occurred within a specific timeframe in a particular district and community, generalizations to past and future could not be made. To prevent this, the research findings were reported as implications that should be repeated at another time to determine if results are consistent. In addressing quantitative statistical analysis validity, reliability was determined with the coefficient alpha. It must be noted, however, that:

> …inferential statistics are based on an assumption of random or representative selection of cases, and error rates in derived estimates of population characteristics are proportional to sample size. Sample selection and sample sizes therefore limit the kind of statistical procedures that might legitimately be used and the capacity to generalize to a larger population. (Bazeley, 2004, p. 147)

Qualitative Considerations

Qualitative validity, by contrast, requires consistency of procedures and accuracy of findings (Creswell, 2009). To provide for qualitative reliability, as suggested by Yin (2003), a PLC meeting protocol was designed and applied, as was a protocol for PLC meeting field notes. Regarding the transcribed PLC meetings, as Gibbs (2007) suggested, the transcription process was carefully reviewed and coding was set and consistently compared to data. To check for the validity of the qualitative data, or whether the findings were accurate, the following strategies were implemented: triangulation of different data sources to construct justification for emerging themes; use of member checking by bringing the final report to the participants for review of accuracy; use of thick description for detailed, shared experience from the participants; and identification of researcher bias, thereby providing context for the researcher's comments throughout the report (Creswell, 2009).

Ethical Considerations

Isreal and Hay (2006) pointed to the essential consideration of ethical issues for researchers to anticipate prior to conducting their study. Such considerations include personal disclosure and privacy, authenticity and credibility of the report, and the cross-cultural contexts of the researcher's role. The primary rule of data collection is to consider all potential risks to the participant population. In efforts to prevent judgment or prejudice against subjects, identifiers were removed and coded data were kept in separate and secure locations. The subject population was small and specific to a particular department within a particular middle school; identification of subjects was not likely to occur outside of the population but the possibility must be considered. In the event that data were lost, stolen, or otherwise compromised, lack of identifiers, codes, and pseudonyms would have prevented subject identification. The research was also submitted for review by the Institutional Review Board (IRB), and prior to any participant research, IRB approval was obtained. All individuals of authority were asked for permission and informed of the details of research to ensure that involvement would have no effect on the employment situation or further negative job repercussions to participants. After a period of 5-10 years, as recommended by Sieber (1998), the data will be destroyed to protect all participants.

Challenge Considerations

As in any research undertaking, challenges were anticipated and prepared for as best possible. The initial organization of the PLC members and pinpointing dates and times suitable to the group were challenges. Maintaining PLC participants throughout the process was also challenging as was identifying, contacting, and arranging leaders and presenters for the PLC. The mixed methods research itself was challenging because of the collection and analysis of both qualitative and quantitative data. Data collection and especially analysis was time-consuming, considering data transformation and creating matrices to combine both qualitative and quantitative data. Even the final report posed the challenge of successfully conveying the mixed methods approach to the audience.

It is recognized that in mixed methods research, "validity stems more from the appropriateness, thoroughness, and effectiveness with which those methods are applied and the care given to thoughtful weighing of the evidence" (Bazeley, 2004, p. 148). Therefore, I provided a rich-in-detail account of the study design, data, collection procedures, and data analysis methods (Creswell, 2009), allowing the reader to interpret the credibility of the research and result implications.

CHAPTER 4. FINDINGS

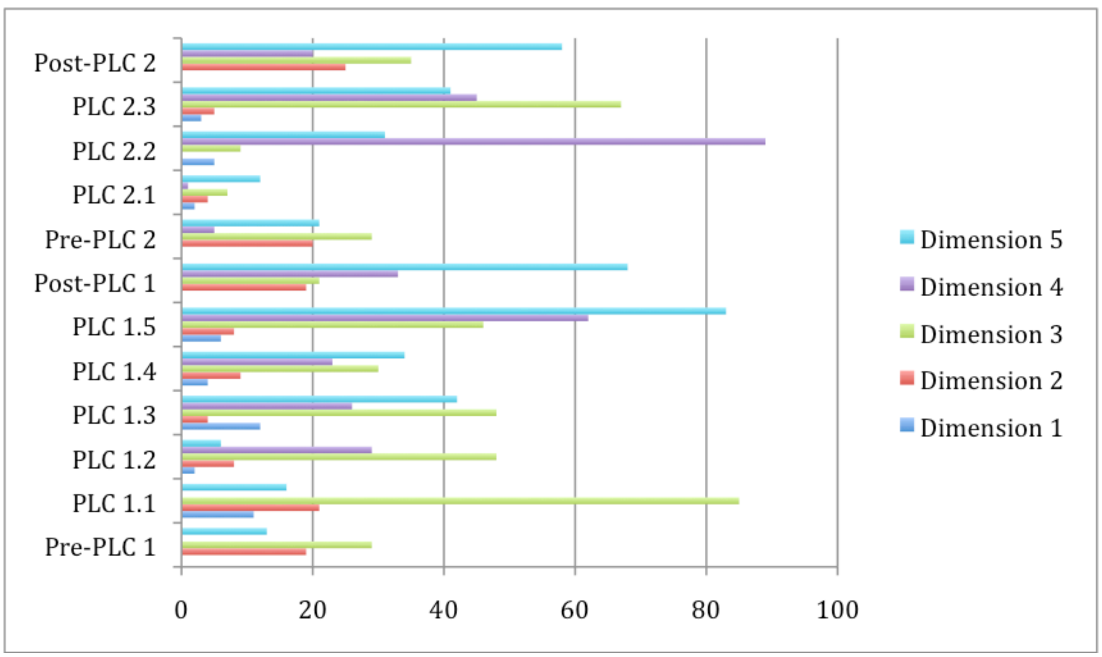
Chapter 4 presents the analysis and emerging research findings from the qualitative and quantitative data collected throughout the science department PLC.

Research Question 1

How did the five dimensions of successful PLCs manifest and evolve as the science PLC progressed?

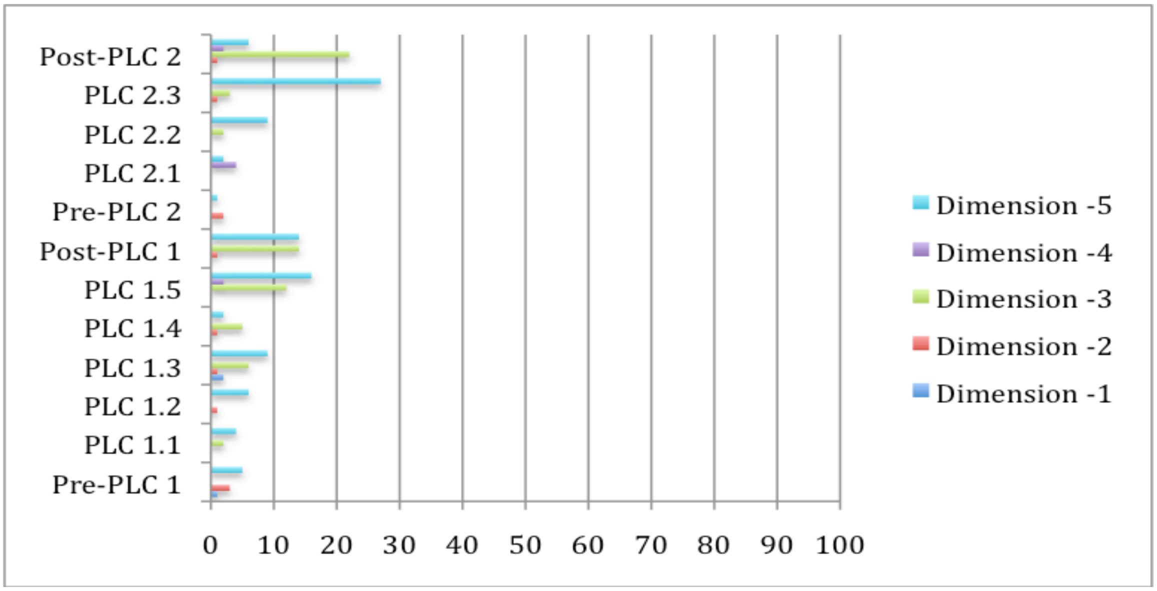
Overall findings demonstrated an increase in participants' positive dimension responses from PLC 1 to PLC 2, including positive trends within each of the PLC experiences. Quantitative mean Likert data revealed an initial weak "Neutral" range response that increased as the PLC progressed from PLC 1 to the final PLC 2 experience. The mixed data revealed that the design, topic, and organization of the science department PLC meetings affected the manifestation and frequency of the dimensions displayed. The mixed data revealed patterns of positive dimension code frequencies decreased and response variation increased between PLC 1 and PLC 2 as well between PLC 2 meetings. Evidence of the manifestation and evolution of the coded five dimensions was obtained from both qualitative and quantitative data sources, which were triangulated during the temporal progression of the PLC sessions. As the PLC progessed through PLC 1 and PLC 2, evidence for changes in the coded dimensions were shown through changes in frequency and mean Likert scale scores.

Figures 4 and 5 display the frequencies for each of code dimensions derived from the analyses of the 682 complete idea units (as defined by Foster et al., 2000; Hunt, 1970; Kroll, 1977) identified in the observation and open-ended reflection data. Figure 4 displays the frequencies of the positive code schemes identified for each dimension, whereas Figure 5 displays the frequencies of the negative code dimension schemes. Comparatively, the frequencies of positive codes were substantially greater than those of the negative codes, supporting the generally positive responses of the participants to the PLC experiences.



Positive Dimension Key: (1) Shared & Supportive Leadership; (2) Shared Values & Vision; (3) Collective Learning & Application; (4) Shared Personal Practice; (5) Supportive Conditions

Figure 4. Frequency Graph of the Positive Dimension Characteristics per Media



Negative Dimension Key: (-1) Shared & Supportive Leadership; (-2) Shared Values & Vision; (-3) Collective Learning & Application; (-4) Shared Personal Practice; (-5) Supportive Conditions

Figure 5. Frequency Graph of Negative Dimension Characteristics per Media

In Figure 6 the Likert scale survey results for all five dimensions where plotted as mean values aligned to the Pre- and Post- Surveys accordingly. The data trends support positive findings for all dimensions as indicated by the overall mean increases. Mean scores were initially within the estimated within the weak "Neutral" range around 2.5, with coded dimesnions 1 and 4 tending towards weak negative responses and dimensions 2, 3, and 5 tending towards weak positive responses. Gradually all dimensions increased towards a final mean value within the "Agree" range, a mean above a 3 on the 4-point Likert scale. The Likert scale survey data also revealed evidence of increased frequency trends for all five dimensions. Therefore, the evidence supports a conclusion that there was increasing positive responses by the participants as the PLC experiences progressed.

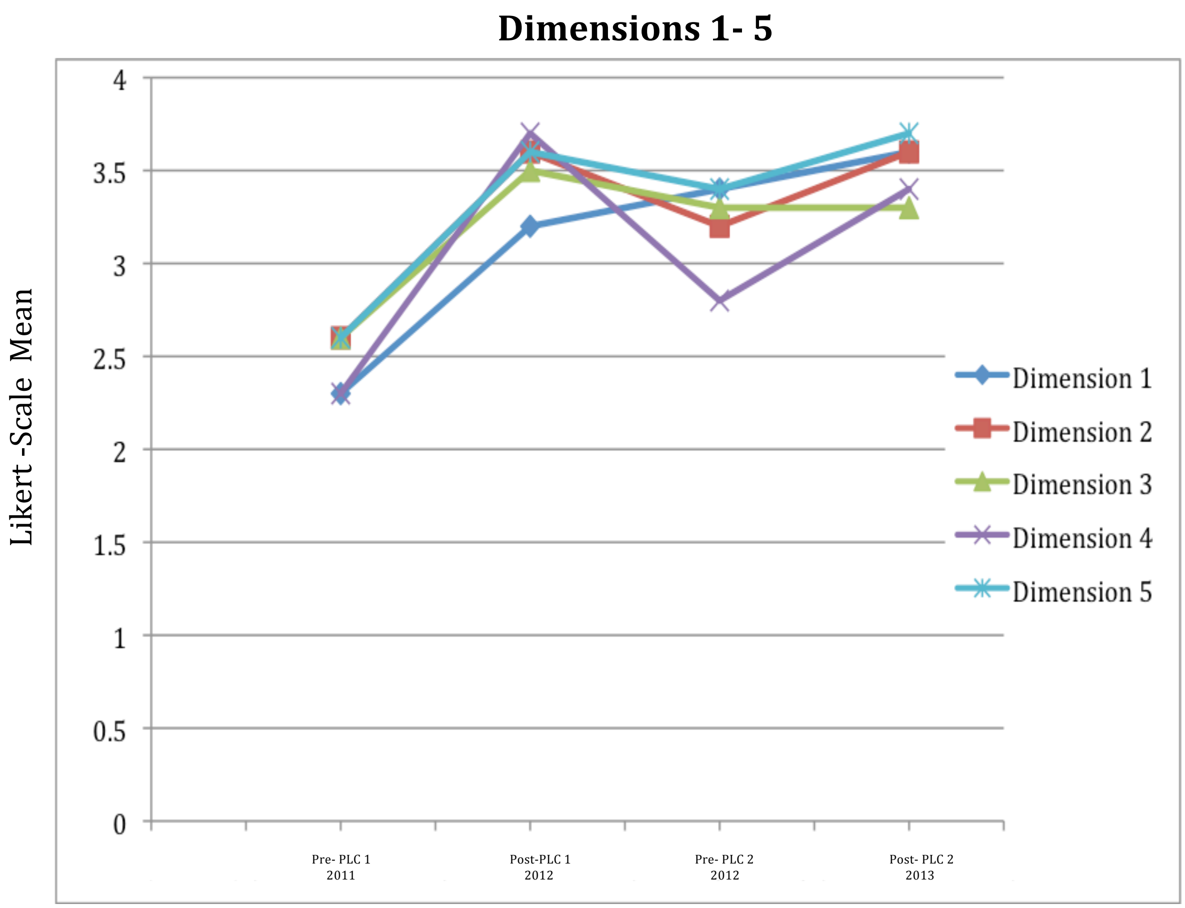


Figure 6. Evidence of Mean Dimension Progression According to the Likert Surveys

PLC 1 to PLC 2

The Likert scale mean values before the inception of the PLC sessions were in the "Neutral" range, thus indicating no particular orientation to agree or disagree. Recall for the 4-point Likert scale, the estimated 2.5 mean was used as a "Neutral" score. As the PLC 1 experiences progressed to the final PLC 2 experiences, the mean values of the Likert scale responses increased. The Likert scale data show that at the beginning of the second year (PLC 2), there was a delcine in the Likert Means relative to the last PLC year 1 meeting. It is not clear why such a decline occurred.

Aligning, triangulating, and mixing the data sets further analyzed the data from PLC meeting observations and survey results to explore the dimension progressions from PLC 1 to PLC 2 in order to identifiy further emergent themes regarding the nature and function of the science PLC process. Figures 7 represents the frequency data for all positive and negative code schemes for all dimensions aligned by PLC meeting number and meeting topics, therefore representing the alignment of the qualitative data sets as the PLC experiences progressed.

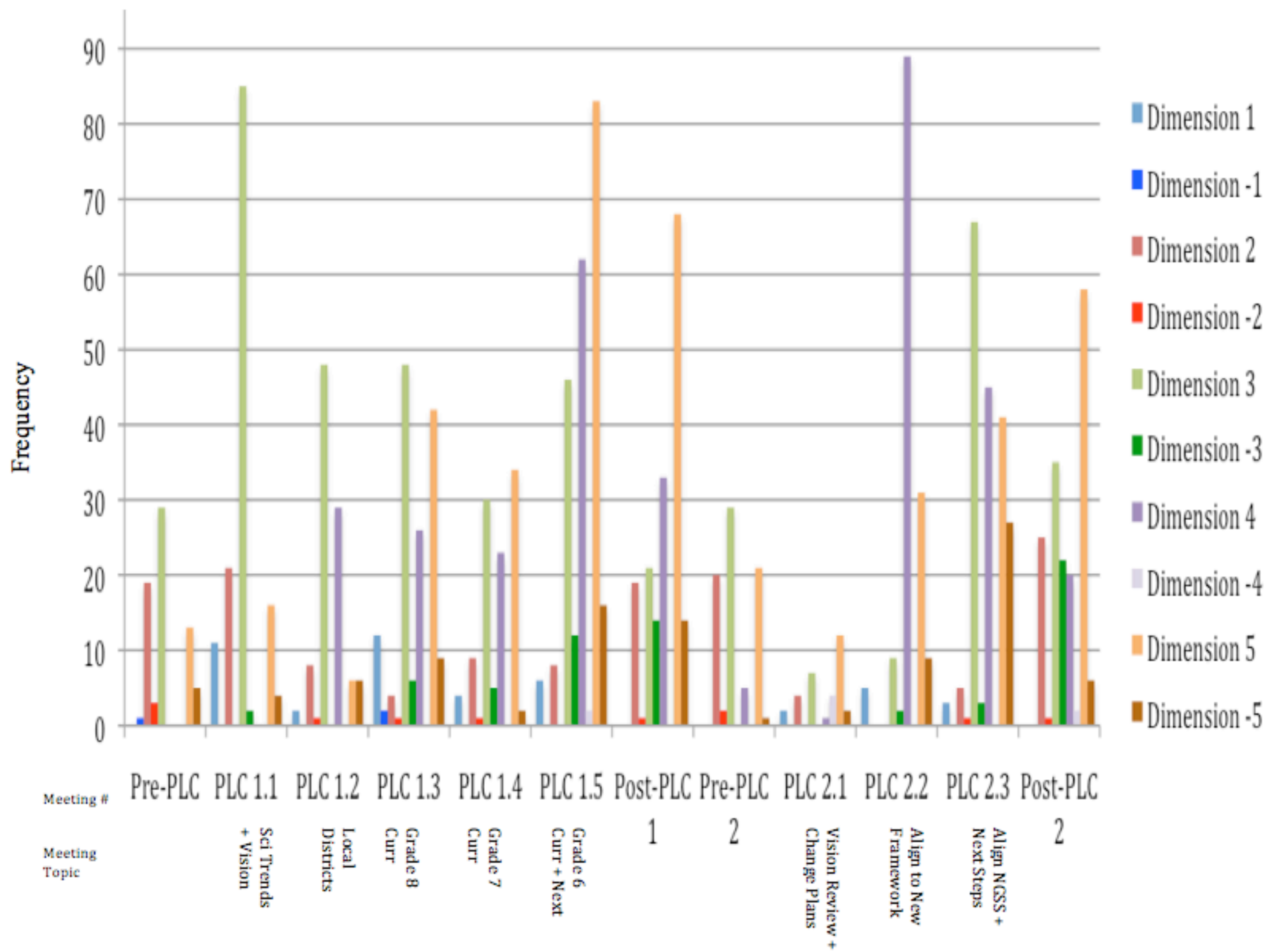


Figure 7. Qualitative Frequency Data for all Dimensions per PLC Media

Alignment and mixing of the qualitative data (Figure 7) supported the overall findings of higher positive PLC dimension aspects in comparison to the lower negative dimension aspects. The inclusion of the PLC meeting number and meeting topics revealed that the science department PLC meetings affected the frequency of the dimensions indicating the influence of PLC meeting topics and meeting organization on the dimensions displayed. One such example was found during PLC 1.1, when a speaker presented current trends in science curriculum, teaching, and learning to the PLC participants. Data from PLC 1.1 revealed high frequencies of positive codes for *Code 3, Collective Learning and Application Dimension*, which were supported by moderate levels of *Code 1, Shared and Supportive Leadership Dimension; Code 2, Shared Values and Vision Dimension;* and *Code 5, Supportive Conditions Dimension*. By contrast, low frequencies of negative codes were idenfied for *Code -3, Collective Learning and Application Dimension,* and *Code -5, Supportive Conditions Dimension.* These relatively low frequencies were likely associated with the participants' preference to have more application opportunites and more time with the speaker. Thus, overall, the data indicate that the the PLC experiences promoted a positive response by the participants.

Table 7 displays the comparison of the overall means for the Pre-PLC 1 Likert Survey (2011) and the Post-PLC 2 Likert Survey (2013) via paired *t* test results. The *t* test results display a two-tailed *P* value of 0.0004 with a 95% confidence interval, which by conventional criteria is considered to be extermely statistically significant.

Table 7

Paired t test for Pre-Likert Survey (2011) and Post-Likert Survey (2013)

Group	**Pre-Likert 2011**	**Post-Likert 2013**	***t* Test (paired)**	***P* Value**
Mean	2.480	3.520	10.614	0.0004
SD	0.164	0.164		
SEM	0.073	0.073		
N	5	5		

Note. The *P* value is > 0.10, the data passed the normality test with *P* > 0.05

Results of the paired *t* test indicated that the Likert survey results from the participating science teachers significantly increased during the science department PLC.

Mixing the data showed that at the beginning of the second year, there was a delcine in both the Likert Means and positive code frequencies relative to the close of the first year. Again in PLC 2 when extra time was scheduled between the PLC meetings for planning, implementation, and reflection, there was a concurrent decrease in positive frequencies as seen in Figure 7. PLC 2 meetings influenced variation in participant agreement on the presence, development, and manifestation of the positive PLC dimension aspects (Figure 6). Multiple instances confirmed the decreased of positive dimension aspect frequency and increased participant variation regarding dimensional presence and development from PLC 1 to PLC 2 (Figures 6, 7, and 8). It is recognized that between PLC 1 and PLC 2 the participants' were working on summer science curriculum development days, which may have challenged positive dimension aspects, or the uncertainty of a new school year may have decreased positive dimension aspect frequencies.

Individual Coded Dimension Findings. Data analysis for research question 1 revealed findings pertinent to each of the individual coded dimensions as they manifested and evolved throughout the science PLC.

Dimension 1: Shared and Supportive Leardership. *Shared and supportive leadership occurred when the traditional role of the adminstrator was broken down and redistributed to the learning community, as seen through collaborative dialogue and the shared responsibility of decision making.*

Overall results for Dimension 1 indicated a positive increase in the *Shared and Supportive Leadership* aspects displayed by the quantitative mean score responses, see Appendix H:1 for complete statistical analysis performed. Figure 8 displays the positive pattern of Dimension 1 survey responses as they increased from the initial Pre- Likert PLC 1 (2011) survey mean of 2.3 in comparison to the finial Post-Likert PLC 2 (2013) survey mean score of 3.6.

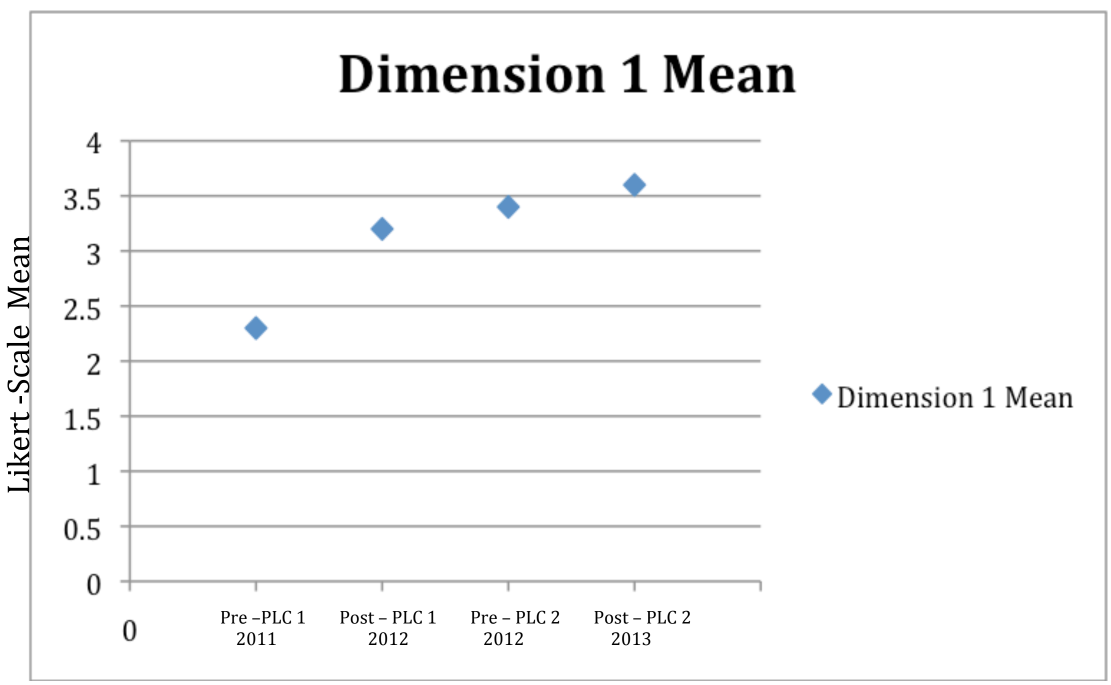


Figure 8. Quantitative Mean Score Responses for Dimension 1

The traditional role of adminstration was precieved to be that of learder, decision-maker, policy enforcer and teacher evaluator according to the participant reflections and researcher field notes. Review of the dimension 1 data revealed the science adminstrators willingness and efforts to reliquish the tradition adminstrative role for that of a ditributed leadership model. The science PLC meetings began with the science adminstrator making conscious efforts to involve the science PLC members in a collaborative dialogue for group decision making and PLC direction. It was in fact the science administrator's suggestion to use and apply the *Tuning Protocol* (Blythe, Allen, & Powell, 2007) to enhance and encourage shared leadership and teacher-directed dialgaue. After open-dialogue discussion, the teachers decided and agreed upon the amendments to the *Tuning Protocol* to best facilitate their needs. As well, the *Tuning Protocol* was led and guided by various science teachers, not the administrator. The administrator at this point relinquished control and allowed the science PLC members to run the meetings and curriculum analysis. Shared leadership essentially was expected by the ending PLC 1 meetings and became routine by PLC 2 meetings.

The mixed data supported the finding that efforts made by the science administrator to transfer authority to better incorporate the science teachers into critical curriculum analysis and decision making utilizing the *Tuning Protocol* were successful.

Dimension 2: Shared Values and Vision. *The PLC engaged individual values and worked to develop a communal commitment to improved student learning.*

The quantitative data revealed a positive increase of the *Shared Values and Vision* characteristics of Dimension 2, see Appendix H:1 for complete statistical analysis performed. Figure 10 indicates the pattern and overall increase in Dimension 2 characteristics from the initial Pre-Likert PLC 1 (2011) survey mean score of 2.6 in comparison to the finial Post-Likert PLC 2 (2013) survey mean score of 3.6. The data pattern in Figure 9 a decrease in participants' agreement of Dimension 2 aspects from PLC 1 to PLC 2, as seen by the drop in the Pre-Likert PLC 2 (2012) survey mean.

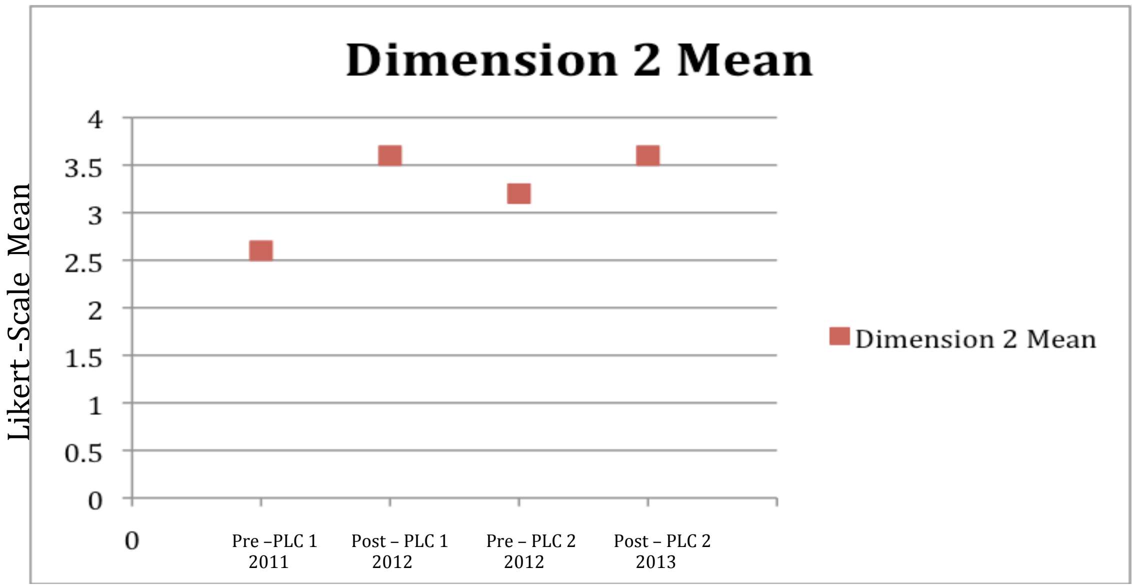


Figure 9. Quantitative Mean Score Responses for Dimension 2

Initially, PLC members worked to define a collective and shared vision based on both individual teacher goals and department goals. Each PLC meeting began with a review of the vision and an open discourse around the participants' views of progression towards the vision or refinement of the vision statement. Over time, the PLC vision was continually reworked; thus, the vision evolved over time with science PLC developments.

> Teacher H: It [science program] would be to best serve our students and our science curriculum to really support changes or tweaks that work to bring our kids towards science literacy and critical creative thinking, you know those 21st century skills. But then there's this mix of all this other stuff in

> there and it’s a struggle; and we don’t want to make another mistake that we have to change in another five years, because that’s what we’ve seen and done historically. We want the best possible curriculum experiences across the grades levels that foster, you know, support science excitement with those smiling faces, growth so they are prepared for the next grade level, and performance on our assessments and the states. (Transcript PLC 1-Meeting 5, 2011)

The mixed data indicated a constant struggle between an individual’s views and the collective science PLC vision. The constant struggle was reflected in both the qualitative and quantitative data. It was necessary for continuous review and refinement of the PLC vision throughout the PLC meetings to preserve relavance and appropriate direction for PLC member buy-in and maintenance of the PLC vision. By the PLC year 2 meetings, the group collective was constantly referring to the revised vision as a means of enlightening the path towards the department curriculum changes, thus providing focus while maintaining flexibility in the direction of improved science teaching and learning through curriculum change.

Dimension 3: Collective Learning and Application. *The PLC functioned to encourage its members to collectively seek new knowledge and information as well as ways of applying that knowledge to teaching and learning.*

Quantitative data revealed an overall positive increase of the *Collective Learning and Application* of Dimension 3, see Appendix H:1 for complete statistical analysis performed. Figure 10 dispays the overall increase in positive survey responses as shown by the initial Pre-Likert PLC 1 (2011) mean score of 2.6 compared to the finial Post-Likert PLC 2 (2013) mean score of 3.3. The pattern of mean score data indicated an initial jump in Dimension 3 positive characteristics within PLC 1. Dimension 3 mean scores then remained consistant throught the remaining PLC 2 meetings.

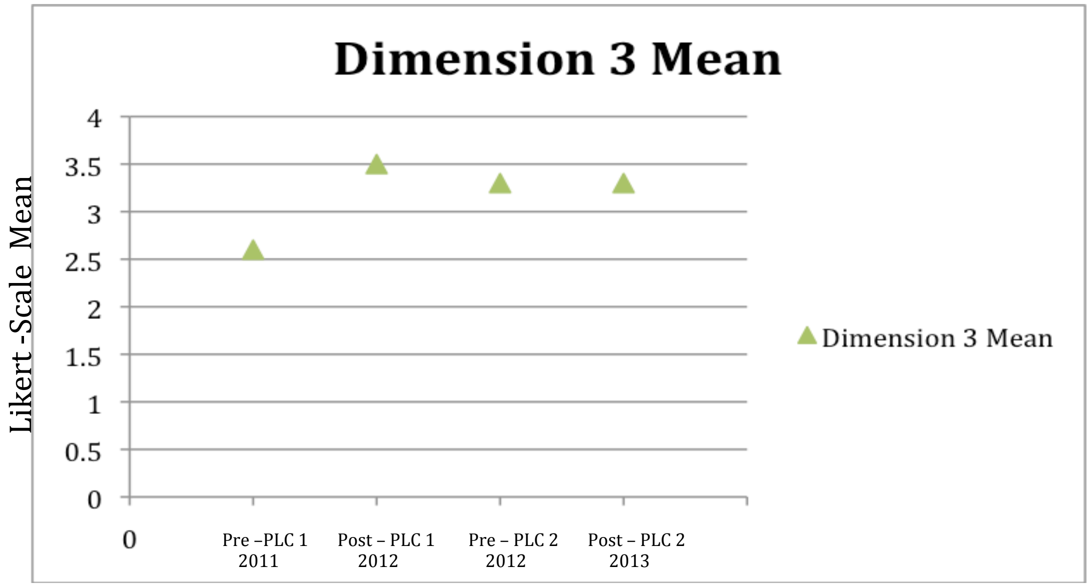


Figure 10. Quantitative Mean Score Responses for Dimension 3

The nature and function of the PLC worked to provide opportunities for learning as well as for discussing and reflecting on ways to apply that knowledge to the teaching and learning of middle school science. Qualitative findings supported that the *Collective Learning and Application* dimension was encouraged through the PLC meeting topics, speakers, and activities. The following reflective dialogue displays how the PLC design encouraged the sharing of learning and the identification of application:

> Teacher I: This is exactly the issue we found in the eighth grade curriculum and our answer was integration. So I think that the key and go-to point is your clarifying question about how to go about the integration of physics and the ecology…
>
> Teacher J: I was looking at your flight thing, the physics of flight and then going back and looking at predator prey and competition and stuff. Look at the connections you could make…
>
> Teacher K: Wow…I don't know why I really didn't see it before, but this could really work…this will be our new focus… (Transcript PLC 1- Meeting 5, 2011)

The negative characteristics of this dimension appeared to represent a general umbrella fear of the fallout from curriculum changes shared by the teachers:

> Teacher A: I think that brings us to some of our huge concerns about if we change, when we change, should we change, not change, do we tread water? I think that's some our concerns as a department or at least at our grade level. I'm not just jumping in there. We've made changes in the past in order to, I believe, to try... I'm not quite sure why we made the last change and I don't want to be in that situation again… (Transcript PLC 1-Meeting 1, 2011)

Overall, mixed data supported that the science PLC generated high levels of learning and application as a result of the collective experiences designated by the PLC participants. Therefore, the structure and functions of the PLC process encouraged collective learning. This in turn led to PLC meetings and activities that were the result of the application of what was previously learned through participation in the PLC. The development of this dimension provided the opportunity for the interchange between collective learning and knowledge application, which ultimately shaped the science department PLC outcomes.

Dimension 4: Shared Personal Practice. *The sharing of practice occurred when teachers work together to plan, reflect, refine, and assess curriculum and instructional startegies used to work towards enhancing student learning outcomes.*

The quantitative data for Dimension 4, as seen in Figure 11, demonstrated an overall increase in the positive survey responses of the *Shared Personal Practice* dimension from the Pre-Likert PLC 1 (2011) mean score of 2.3 to the finial Post-Likert PLC 2 (2013) mean score of 3.4, see Appendix H:1 for complete statistical analysis performed. The pattern of the mean score data revealed a drop in means scores from PLC

1 to PLC 2 for Dimension 4 indicating an decrease in participants' agreement with the positive characteristics of Dimenion 4 from PLC 1 to PLC 2.

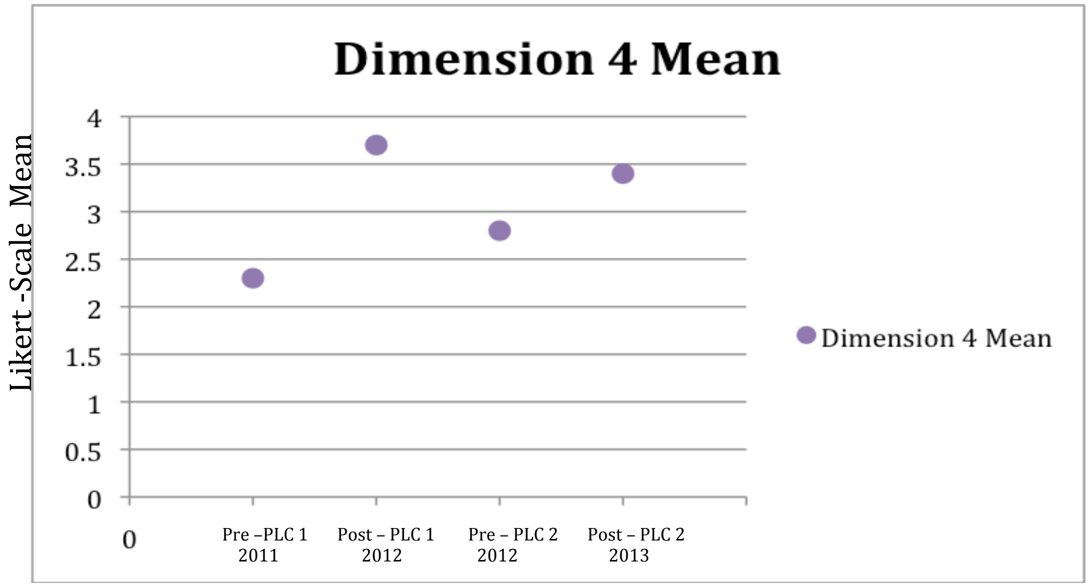


Figure 11. Quantitative Mean Score Responses for Dimension 4

Initially, PLC participants were reluctant and unsure of how to go about the sharing of personal practice, as noted by one member: "It is not the culture of the school to share and critically evaluate peers' teaching methods, strategies, and curriculum. That has always been an administrative role" (Post-Open-Ended Reflection, PLC 2, 2012). With the application of the *Tuning Protocol* (Blythe, Allen, & Powell, 2007), members were able to utilize a routine of critical analysis of curriculum and pedagogy without the evaluative feel of an administrative assessment. As the members shared curriculum and pedagogy, continually gaining familiarity with the protocol, feedback progressed in value and utilization towards the goals for curriculum change. Observed negative instances of this dimension reflected the adjustments desired by the PLC members for the protocol to allow for more flexibility in discussion and feedback time, e.g., “Not enough time was spent with team (grade level) opportunity to apply shared learning and results. I would love more of these opportunities.” Negative characteristics were also identified by participants in lacking opportunities outside of the PLC for coaching, mentoring, and observational feedback.

The combination of the quantitative and qualitative evidence supported the findings that the *Shared Personal Practice* dimension was rooted in the PLC group norms and the tool utilized for the sharing of practice, the *Tuning Protocol*. With the application of the *Tuning Protocol* (Blythe, Allen, & Powell, 2007), members were able to utilize a routine of critical analysis of curriculum and pedagogy, which resulted in the increased opportunity and ability for shared practice by the PLC participants. Essentially, the tool provided a norm routine that made the sharing of practice and critical analysis expected and fluid.

Dimension 5: Supportive Conditions. *Structural: Structural conditions were reflective of the positive use of time, communication procedures, proximity of teachers, size of PLC, and professional development.*

Relationships: Supportive relationships were demonstrated via positive and encouraging dialogues and will be displayed via positive educator attitudes, widely shared and supported vision and PLC purpose, norms of critical analysis and inquiry, respect, trust, and positive caring relationships.

Quantitative data revealed a positive display of the *Supportive Conditions* survey responses of Dimension 5 as indicated by the initial Pre-Likert PLC 1 (2011) mean score of 2.6 compared to the finial Post-Likert PLC 2 (2013) mean of 3.7, see Appendix H:1

for complete statistical analysis performed. The data pattern displayed in Figure 12 indicated an overall positive progression of Dimension 5 characteristics.

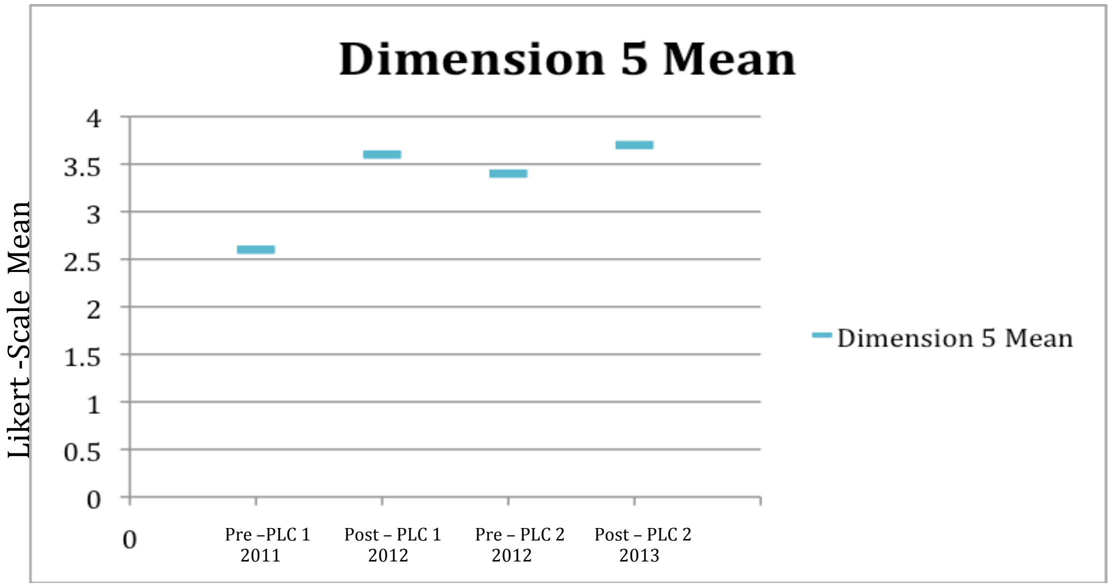


Figure 12. Quantitative Mean Score Responses for Dimension 5

The supportive structural conditions of the dimension were found to be mainly the responsibility of the PLC designer and facilitators, requiring considerable planning and time. Qualitative data revealed that structural support required the consideration of time, space, personnel, and material resources for the PLC to run smoothly and conveniently and to be sustained over time. Once the initial structural factors were in place and appreciated, the PLC was able to progress without concern for structural conditions, as shown by the lack of negative dimensional displays. Thus, the structural support dimension was not as prevalent in the PLC coding frequencies until the Post-PLC surveys. Upon surveyed reflection, PLC members were able to appreciate the structural supports in place for the function of the PLC. Negative instances of supportive conditions came mainly in the complaint of wanting additional time or resources, and not for the lack of resources.

The relationship aspects of the dimension revealed that participant relationships transitioned from collegial to that of critical and collaborative. As the *Tuning Protocol* laid out the routine of presentation, clarification, questioning, reflection, and warm and cool feedback, the members of the PLC became comfortable with the routine and more willing to share, as shown through dialogue of both positive and negative reflections, respect via listening and speaking in turn, and comments of recognition and appreciation. Supportive relationships developed over time, but once present the feeling of collaboration and readiness to "P-L-C," as the group coined it, was noted by the researcher in field note observations. The negative instances of the supportive relationship dimension, were reflected in expressions of frustration by teachers who, even with the suggestions of the PLC science teacher participants, had not been able or willing to make curriculum changes:

> Teacher K: We're depressed in seventh grade.
> Teacher L: I know. I can tell.
> Teacher M: No, we're out to join you.
> Teacher N: You guys look very sad.
> Teacher O: That's the look of frustration, I know it well.
> Teacher K: We, and please everybody jump in. We feel that the feedback we got from the last PLC was definitely valid, but we've done nothing to address it. We continue to spin our wheels trying to find time and topics and we had scaled back…but then the new framework and then now this new next generation…we're not willing to take the chance on that right now… (Transcript PLC 2 - Meeting 3, 2012)

Although the above teacher group expressed the inability to make changes to their curriculum, they were supported by the PLC group to continue their efforts and encouragement that changes would allow the team more flexibility in the future. This interchange supported the finding of the transition from collegial relationships to critical and collborative relationships through the PLC process even though particiants struggled with curriculum change.

Mixed data supported the findings that when the structural conditions and requirements were properly in place, the PLC meetings could progress. As the meetings progressed, supportive relationships, encouraged by the design of the PLC process, changed from participant collegiality interchanges to critical and collaborative exchanges as the PLC participants worked towards curriculum change.

Research Question 2

What were the actions and outcomes of a PLC focused specifically on a science department?

Research question 2 was designed to delve into the actions and outcomes resulting from the science department PLC looking to identify whether applying a PLC model within a science department would lead to science-specific results, thus indicating a specific application of a science PLC for science departmental use. The identified actions and outcomes highlighted the unique ability of science PLC to focus on the science departments' specific needs regarding science curriculum changes in light of the school culture, community and climate.

The findings revealed that the science department PLC was as a unique interface for the science teacher participants to look at science teaching and learning within the context of school culture, community, and climate. It was found that a science department PLC was particularly unique in providing the means and opportunity for the science teachers to contextualize their specific science curriculum change issues within the larger context of school and educational climate. Additionally, the science department PLC was found to provide support for the science teachers in their efforts to make science curriculum changes as they traversed the multifaceted challenge of curriculum change in light of district, school, state, and educational initiative pressures. The science PLC provided the unique opportunity for growth specific to middle school science teachers' science curriculum change efforts. Essentially the science department PLC allowed the science teachers to tackle the larger issues in the educational system through the smaller context of science teaching and learning at the middle school grade levels. The evidence was provided in identifying the *actions* and *outcomes* of the science department PLC through the *Collective Learning and Application* and *Shared Personal Practice* dimensions.

An *action* was defined as an act, a deed, a function, or a movement working towards the science PLC's defined vision and goal. An *outcome* was defined as results, products, conclusions, or something otherwise made or created by the actions and function of the science PLC. The *Collective Learning and Application* dimension was found essential in exploring the characteristic *actions* of a science department-focused PLC. The distinguishing characteristics of this dimension supported the PLC's functions: encourage its members to collectively seek new knowledge and information as well as ways of applying that knowledge to teaching and learning. The PLC focused specifically on the middle school science department allowed for the utilization of the structure, function, and nature of a PLC to the specific needs and desires of that department's efforts in school-based science curriculum change. The *Shared Personal Practice* dimension was essential in identifying the specific *outcomes* of a science department-focused PLC. The distinguishing characteristics of the dimension identified the science teachers' curriculum change plans, reflections, refinements and assessments on curriculum and pedagogical strategies that worked towards the goals of science curriculum change. In Table 8, the identified *actions* and *outcomes* from the science PLC have been arranged by PLC year.

Table 8

Action and Outcomes of a Science Department PLC Engaged in Science Curriculum Change Efforts

PLC 1 (2011 – 2012)		**PLC 2 (2012 – 2013)**	

Actions
○ Investigated the current trends in science curriculum changes and standard development
○ Investigated the curriculum science educational concerns of two local districts
○ Conducted a complete critical review of each science grade level's (6-8) scope and sequence
○ The PLC meeting protocols encouraged
  ○ Definition of vision
  ○ Support of structural and relationship development
○ The PLC use of the *Tuning Protocol* encouraged:
  ○ Dispersed leadership
  ○ Collective learning and application
  ○ Shared person practice
○ Designation of summer days to further the efforts
	Outcomes
	○ Enhanced the awareness of the courses and coverage of science in and between grade levels identifying areas of strength and weakness
	○ Learning progressions across sixth, seventh, eighth grade science practices and skills were identified and reinforced
	○ The design of a common rubric for all lab skills
	○ The initial discussion and planning for common assessment within grade levels
	○ Identified middle science curriculum areas requiring improvement:
	  ○ Integration of grade 6
	  ○ Overwhelming topic coverage of grade 7
	  ○ Disconnect in grade 8 topic coverage
	○ Summer Curriculum Days:
	  ○ Common science rubrics
	  ○ Grade 6 integration and new sequence/ curriculum plan
	  ○ Assessment development 6-8
	  ○ Collaborative work with elementary science curriculum
		Actions
		○ Engaging in discussion about improved vision statement
		○ Members discuss and assess developed curriculum changes
		○ Members participate in discussions of current science education teaching learning and issues
		○ Grade-level groups and aligned scope and sequence to the *New Science Framework*
		○ The grade-level PLC groups aligned scope and sequence to the NGSS
		○ The PLC meeting protocols encouraged
		  ○ Redefine vision statement
		  ○ Support of structural and relationship development
		○ The PLC use of the *Tuning Protocol* encouraged:
		  ○ Dispersed leadership
		  ○ Collective learning and application
		  ○ Shared person practice
		○ Designation of summer days to further the efforts
			Outcomes
			○ A new science vision guiding curriculum change and department goals
			○ Grade 6 curriculum realignment was revisited, reflected, and further improved
			○ Grade 7 was unwilling to change because currently it is aligned to state standards and test
			○ Grade 8 is aware of more consistency and reflecting on a lab-based curriculum
			○ Scope and sequence was aligned to the New *Framework* to identify areas of strength and weakness
			○ Scope and sequence have begun to be aligned with the NGSS
			○ Summer Curriculum Days:
			  ○ Align labs with the common 6-8 rubric (Science Practices)
			  ○ Continue curriculum development work 6-8
			  ○ Assessment development 6-8
			  ○ Collaboration with elementary science developments

The *actions* that occurred were specific to the science department in that the learning opportunities and situations focused on the goals of a middle school science department situated within the larger school climate and science educational developments. Review of the Dimension 3 *Collective Learning and Application* data revealed an increase in both qualitative and quantitative frequency and mean scores respectively from the Pre-PLC 1 surveys to the first PLC 1 meeting. The implication of the data with consideration of the identified *actions* of the science PLC was that collective learning occurred as a result of the PLC meetings. PLC 1 meetings specifically included visitors and presenters; a science education professor, local middle school science department teacher speakers, and the science teacher PLC members sharing their own grade-level scope, sequence, and plans for curriculum changes; to encourage science specific knowledge and learning. The science department PLC was able to cater learning to the developments, discussions, and presentations of science education, middle school science scope and sequence, common science practice rubrics, and science teaching and learning reforms that included the *Framework for K-12 Science Education* (NRC, 2012) and the Next Generation Science Standards (NGSS). Through collaborative and reflective dialogue, the science teaching and learning information was incorporated into the science department's science curriculum and pedagogy as shown through the identified *outcomes* of PLC 1 and PLC 2. The overall implication is that science department PLC provided the opportunity for its members to plan for school-based science curriculum changes and to reflect on implementation for further development to the middle school's science teaching and learning program.

Discourse among the science teacher PLC participants focused on the science teaching and learning issues directly affecting the middle school science teachers. Discussions were therefore proximal; related to school culture, community, and climate; and focused on the issues that affected science teaching and student learning outcomes. The interchange below from PLC 2 - Meeting 3 Transcript (2012) is a PLC participant conversation that outlines the struggle the teachers had when considering the value and importance of incorporating the district goals into a middle science curriculum while trying to balance state standards, NGSS, department goals, and district goals for the ultimate goal of high levels of student science learning outcomes:

> Teacher E: …There's a lot of frustration expressed when we're having these discussions…for example, the concepts of teachers pushing kids to go beyond, to go and think and reason through problems…but then who does that upset? It upsets the kids because they're not succeeding. It upsets the parents because their kid is not succeeding. It frustrates the teacher because the teacher is struggling to lead kids to higher levels which is a process…so it's like, it's this bizarre back and forth between yeah, you want to push them…you want to challenge them…you want to do that and simultaneously, it's all tangled together…
>
> Teacher F: It's between what's right and what's easy or makes the most sense for all involved, kids, teachers, parents, tests, sometimes with eighth grade we have a real struggle and debate about it.
>
> Teacher E: That's a point we are making as a group.
>
> Teacher I: The education for the future—teach all content but not too much and be sure to tie in technology, critically and creative thinking, common core…. All are important, all I believe in, but the struggle is how realistically does this translate into the curriculum and pedagogy of a single school year?

The result of the science department PLC's critical discussion and analysis was overall growth in the learning and application in the department's current science education knowledge and development. This was further supported by the qualitative and quantitative results from the *Collective Learning and Application* dimension, which as noted, displayed a high frequency in both the qualitative data and quantitative data. The

Pre-2011 mean score of 2.6 increased to the final PLC 2 Post-2013 mean score of 3.3, indicating that the science department PLC did encourage the science educator members to collectively seek new knowledge and ways of application through collective dialogue, reflection, and collaborative solution seeking. Thus, a science department-focused PLC provided the middle school science department with an interface focused specifically on its explicit efforts for school-based science curriculum changes.

The *Shared Personal Practice* dimension indentified the specific *outcomes* of a science department utilizing a PLC model for science curriculum change efforts. This dimension was evidenced when the teachers worked together to plan, reflect, refine, and assess curriculum and instructional strategies used to work towards enhancing science student-learning outcomes. The *Tuning Protocol* was implemented to facilitate PLC science department members sharing of grade level science scope and sequence and reflecting on middle school science curriculum and learning outcomes. The presentation of the grade-level science curriculum in PLC 1 resulted in the development of grade-level scope and sequence by each teacher in each grade level. Review of the qualitative and quantitative data for Dimension 4 revealed increased frequencies and mean scores respectively from the Pre-PLC surveys to the Post-PLC surveys. Consideration of the data and the indentified *outcomes* implies that it was the PLC meetings and protocols that allowed for reflection of science scope and sequence within and across grade levels to develop the science department PLC curriculum change *outcomes*. Collaborative dialogue encouraged by the *Protocol* resulted in changes and improvements to the middle school's science scope and sequence (Appendix I:1) and student learning outcomes which included the development of a common rubric for progressive 6-8 science skills and practices (Appendix I:2); the identification and development of middle school science scientific and engineering learning progressions (Appendix I:3); the integration of the new science *Framework for K-12 Science Education* (NRC, 2012) for a more authentic science experience (Appendix I:4); and the alignment of local assessments to inform science-learning outcomes.

In PLC 2, grade-level teachers aligned their scope and sequences with the Disciplinary Core Ideas of the *Framework for K-12 Science Education* (NRC, 2012) and additionally aligned their lessons and activities with the Practices for K-12 Science Classrooms and the Seven Cross-Cutting Concepts of the Framework. The presentation of framework alignment led to reflective discourse and further improvement and reinforcement of the middle school science curriculum in the form of 6-8 lab alignments with the common rubric, refining local assessments, and further topic integration. All *outcomes* of the science department PLC involved improvements to the middle school science curriculum via informed department-based curriculum changes.

In the open-ended response questions from the Post-PLC 2 survey (2013) the participants responded to the ability and *actions* of a PLC focused solely on the science department in accomplishing *outcomes* and departmental goals:

> The PLC provided an actual time and place for the department to meet together and really take apart the curriculum.
>
> The process of the PLC, the in-depth analysis and discussion, these were results of the meetings and allowed for the change/improvements we [the science department] are making.

When asked to explain if they felt the PLC would be useful to other science departments in their efforts towards departmental specific *outcomes*, the community gave responses like the following in the Post-PLC Open-ended Responses (2011-2012):

> Absolutely. It [the PLC] promotes collaboration not just at grade level but also throughout the department. Some great ideas have been bounced around the meetings. And we are sharing many of the same frustrations…united in our struggles we work to come to solutions.

> Yes—it is a place for a department to identify and discuss issues within and throughout grade levels. It encourages listening, understanding, and sympathy of the efforts of teacher at all levels. It provides a means to explore possible solutions that come from the department or from outside sources/experts. It is a great teacher tool to deal with issues and the constant changes in standards and requirements.

As seen through the identified *actions* and *outcomes* (Table 8), the science department PLC was able to contextualize school, community, and education issues through a science department lens, leading specifically to science department curriculum changes; this highlights the uniqueness of what the science department PLC offered. This science department PLC worked to address and support the science department's goals of school-based science curriculum changes as they applied to the specific department's needs within the school culture and considering the proximal educational situation. The *actions* were directed by the science department through the PLC, which led to *outcomes* that were proximal to the school, department, and teachers, thus having the greatest potential of sustaining success. These motions and outcomes are unlike those of a traditional PLC or PD which tend to carter to more general educational issues, thus allowing for science-specific growth with implications for further application to the context of science disciplines.

Research Question 3

How did the actions of the science PLC facilitate or impede the science department's goals of school-based science curriculum change?

Overall findings indicated that the action of developing and defining the science department PLC vision was essential to participant buy-in and the PLCs' science curriculum change direction while maintaining congruence to district and school goals. This supported the discovery that the PLC vision was not static, providing a flexibility of relevance and direction guidance for the science PLC goals, actions, and outcomes. Yet throughout the PLC, participants and PLC goals were found to be impeded by participant frustration and the inability of the PLC to solve all science curriculum change issues.

In an effort to uncover the actions of a science department PLC that facilitated and/or impeded goals of science curriculum change, I reviewed in detail the data and results from the *Shared Values and Vision* dimension. An *action*, as defined in research question 2, was identified as an act, a deed, a function, or a movement working towards the science PLC's defined vision and goal. I identified the actions of facilitation that could be capitalized on in future science department PLCs, as well as impeding actions that could negatively affect PLC goals of school-based science curriculum change.

The *Shared Values and Vision* dimension involved the PLC participants engaging individual values while working towards developing a communal commitment to improved science teaching and student learning. By tracking the actions that progressed throughout the science PLC through its vision development, I identified how the actions of the science PLC facilitated or impeded the goals of school-based science curriculum changes. Findings indicated that as the science department vision was being developed, the PLC members were careful to consider the district goals, keeping the vision respectfully attuned to district and school desires, while at the same time not allowing the vision to be dictated or imposed by such goals. The science department PLC vision, while functioning within the larger school district, remained separate and unique to the science department's desires of science curriculum change. The excerpt below was stated in a meeting protocol discussion of PLC vision and displays the respect for the district and middle school goals of critical and creative thinking, 21st century student skills, and state assessment performance while highlighting the science department's vision of enhanced student learning experiences through science department curriculum changes:

> Teacher H: It [science program] would be to best serve our students and our science curriculum to really support changes or tweaks that work to bring our kids towards science literacy and critical creative thinking, you know those 21st century skills. But then there's this mix of all this other stuff in there and it's a struggle…. We want the best possible curriculum experiences across the grades levels that foster, you know support science excitement with those smiling faces, growth so they are prepared for the next grade level, and performance on our assessments and the states (Transcript PLC 1 - Meeting 5, 2011)

A second major finding occurred from tracking the vision statement from PLC 1 through PLC 2 and indentifying that the science PLC vision statement was not static. The science department PLC reviewed the vision at each PLC meeting (according to the meeting protocol) and reworded or tweaked the statement until the PLC participants collaboratively agreed the statement was in line with the goals and direction of the science PLC. This ability to manipulate the vision provided flexibility, meaning, and buy-in into the vision statement and its guiding direction for the science department PLC, and thus for the PLC's actions and outcomes.

The initial evidence regarding the vision findings was identified through the action of vision clarification, which in turn facilitated the science PLC in all proceeding outcomes. The vision statement provided focus for the science PLC. Thus, the action of continuous review and revisiting of the vision statement at the beginning of each PLC meeting reinforced the PLC purpose and goals. It was the interactions of the science department PLC vision refinement at each meeting that allowed for individual clarification and collective buy-in of the department vision and goal. When the vision statement seemed out of line with the current direction, understanding, or desires of the science department, it was tweaked until the PLC science department participants collectively accepted the vision and goals, as seen in the exchange below taken from Transcript Meeting 3:

> Teacher D: Right, I was just thinking about our PLC goals, or vision, right? Our initial goal has been severely redefined, which I think is a really good thing, because it focuses us on what we want, can and cannot do. From our PLC discussions, meetings and discussions so far, it seems like the best possible path for science curriculum change in the current middle schools is just small tweaking grade-level topics. The identification of specific science skills and sciences taught at each grade level, and to what extent, and the development of a department rubric or rubrics which show the progression of science skills and practices throughout the middle school and science experience. It seems like that's going to be best in leading us and our curriculum towards this new framework, and what the framework is going to require…. (Transcript PLC 1- Meeting 1, 2011)

With a clear and collective understanding of departmental needs and vision, the PLC facilitated motion towards departmental goals of school-based science curriculum changes as the group was unified in its efforts and understandings. As the PLC progressed in PLC 2, the members made suggestions for amendments/improvements to the PLC vision statement. The participants' desires to alter the vision indicated their ownership and understanding of the science department's goals of curriculum change for the enhancement of science learning outcomes. By the final science PLC meeting, the members resonated with the following understanding of vision for the science PLC:

> We want a science program scope and sequence that…best serves our students and our science curriculum to really support changes or tweaks that work to bring our kids towards science literacy and critical creative thinking and those 21st

> century skills.... We want the best possible curriculum experiences across the grade levels that foster and support science excitement with those smiling faces, growth so they [students] are prepared for the next grade level, and performance on our assessments and the states. (Transcript PLC 2 – Meeting 5, 2012)

As one participant noted in the final PLC 2 open-ended reflection (2013), "I believe the science department has worked to together to formulate a vision and understanding of departmental goals…" The science PLC vision facilitated the actions leading to the production of scope and sequence for grade-level topics, pedagogy, and time usage at every grade level by every participant.

When asked to identify the actions specific to the science department PLC that facilitated departmental vision/goals and the functional actions of the PLC aided in the accomplishment of the defined science PLC vision, the PLC open-ended reflections (2011-2012) fell into specific categories, as presented in Table 9. The data show that the participants' actions of collaboration, discussion, reflection and critique, idea sharing, awareness, analysis, and examination all facilitated the science PLC in progression towards the PLC vision.

Table 9

Facilitating Actions of the Science Department PLC

Identified Facilitating Actions	**Science Department PLC Participant Comments**
Discussion Opportunities	"It has provided grade levels the opportunity to have fuller, longer, deeper discussion"
Reflection & Critique	"Chance to look at and critique the grade-level scope and sequence" "Reflection on the grade-level sequence in relation to the department scope and sequence"

Table 9 continued

Identified Facilitating Actions	Science Department PLC Participant Comments
Awareness	"Helping others see things in their own curriculum" "Aligning grade-level teachers"
Examination Table 9 continued **Identified Facilitating Actions**	"We have used the time provided to examine the changes we have implemented and what results have come from the changes" **Science Department PLC Participant Comments**
Idea Sharing	"We have started to generate excellent ideas that can be supported by each member of our department" "Constructive ways to make some changes"
Analysis	"Learning about the other grade-level curricula and having other peer perspectives presented to solve our content problems" "The process of the PLC and the in-depth analysis and discussion that were a result of the meetings"
Collaborative Meetings	"The ability to meet informally with the entire science department" "Collaboration on grade level—we need more of that"

Actions that impeded the science department PLC were those defined as acts, deeds, functions or movements that worked contrary to the science PLC's vision of school-based science curriculum change. When asked to identify functional actions from the PLC process that did not support progression towards the PLC vision, the participants' responses fell into the following three general categories: meeting time usage, group participation, and frustration, as defined from the participant reflection responses (Post-PLC 1 and 2, Open-ended responses, 2011-2012), presented in Table 10.

Table 10

Impeding Actions of a Science Department PLC

Identified Categories of Impeding Actions	Participant Responses to … What actions impeded PLC goals?
PLC Meeting Structure	"Need time to work on things discussed between meetings" "It [the PLC] is ending for this year…I would like to continue with the work started" "It would have been more beneficial to meet once a month to ensure time for implementation and reflection"
Group Participation	"Not 100% participation which may hinder grade-level progression"
Frustration	"In general, the sheer size of some changes require more time than was available during the PLC" "I do not see our issues being resolved. I feel a lot of this is because the state and its use/implementation of the NGSS is still in flux" "It is hard to make changes and fixes when we don't know what the state is throwing at us next" "Some curriculum concerns have not been addressed—but not the fault of the PLC" "Not much actual change has occurred at my grade level" "Grade 7 has grown in awareness but is reluctant to make any actual changes due to the uncertainty of standard changes and state test"

A review of the impeding action data indicated that meeting structure was a sensitive matter for the science department PLC when working towards its goals. The PLC meeting structure needed to be appropriate and productive during the PLC meetings. Meetings were identified as impeding factors when meeting structure was perceived as inefficient therefore impeding work towards the science PLC goals. Data also revealed that the group participation in the science department PLC was essential to science curriculum change goal progression. The PLC participants perceived cases of lacking participation within the PLC meetings as impeding the efforts towards the vision of school-based science curriculum changes as noted in Table 10 and from research field observations that PLC participants regretted the lack of 100% department participation in the PLC (recall $N = 10$ of the 12 middle school department members). The final major impeding action resulting from the data was identified as PLC participant frustration. As the science department identified and explored modes of science curriculum change, they encountered roadblocks. These barriers to progression included limitations to changes due to state standards, the wide range of stakeholder consideration when designing changes, the slow rate of change enactment, reluctance of grade levels to make changes, and the inability to identify the "right solutions." These sentiments of barriers and frustration are outlined in the excerpt below:

> These changes are in their infancy and will take time. Grade 7 has grown in awareness but is reluctant to make any actual changes due to the uncertainty of standard changes and state test; I do not see our issues being resolved. (Post-PLC 1, Open-ended responses, 2012)

Therefore, the roadblocks to science curriculum change progression were identified as resulting in participant frustration that impeded movement towards school-based science curriculum changes.

Thus, the overall finding for the actions that impeded the science PLC goals of school-based science curriculum change resulted in the participants realizing that the PLC was not meant to solve problems, an unrealistic expectation expresses by participants. The conversation below outlines a discussion between PLC participants during the PLC 2.3 meeting (Transcript PLC 2 – Meeting 3, 2012) regarding the functional purpose of the PLC not to solve problems but to understand and explore them:

> Teacher F: I think that's something that is good about the PLC, it lets us have these conversations. The frustration I hear from the seventh and the eighth grade is real frustrations and comes from not solving all the problems. I know that is disappointing but it's also good to hear too because I guess, sometimes we get wrapped up in our own teaching world and we don't hear or have these conversations that we are considering now through the PLC. Everyone's having these same types of struggles and now we know it—the where, why, and how. But I think that's also the nature of teaching, that we'll never have an exact answer only the best possible solution based on the finding of the times. I don't think there are the proper or correct answers. I think the key is these discussions that lead us to proper or to better teaching and learning as we see it, as research finds it.
>
> Teacher G: I do agree, we have come a long way in understanding and we are working on finding what works best for our grades, topics, kids but not having answers is frustrating. What do we do than, keep searching I guess?
>
> Teacher B: I think it's the only thing we can do, continue to fight the good fight with as much support from the ed. world and each other as we can.
>
> Teacher D: I do think it also means that that frustration piece is never going to go and I feel particularly bad for the eighth grade who's going to feel the pressures because of the state and the testing. I would hope that through this [the PLC], maybe some of the frustration could be released or at least voiced. The grade level supports we have begun and designed should at least provide the solid scientific foundation to support the direction you are taking your kids and then we [the department] want our students to go….

It is the nature of the PLC that allows for actions that facilitate changes to the science curriculum: "A PLC is a group of colleagues working together with a structure forum towards common goals. The PLC discusses education issues and works to collaboratively find/suggest solutions that are bottom-up and meaningful within our community" (Post-PLC 2, Open-ended responses, 2013). But it must be expected that the path of the PLC will at times elicit actions that work against the vision statement: "In general, the sheer size of some changes require more time than was available during the PLC" (Post-PLC 2, Open-ended responses, 2013). It was essential for a science department PLC to recognize that the PLC provided the unique forum for actions that facilitated work towards the PLC goals, but the PLC was not meant to solve problems - thus the appearance of impeding PLC actions.

Research Question 4

What external and internal factors facilitated or inhibited the functions of the science PLC and science curriculum change goals?

The findings for research question 4 indicated that the science department PLC was influenced by both internal and external factors when considering science curriculum changes. The internal factors identified were the middle school administration support levels, relationship developments between PLC participants, and the structural supports and resources available to the PLC. All internal factors were deemed facilitating expect for time and teacher proximity which were seen as inhibiting to the PLC process and goal attainment. The external factors were identified as district administration support levels, district goals, and state standards and assessments. District administration and district support were deemed as facilitating whereas school district goals that included state standards and assessments were identified as inhibiting to the PLC efforts of school-based science curriculum change.

The goal of this final research question was to take a closer look at the results of the *Shared and Supportive Leadership* and *Supportive Conditions* dimensions to explore the internal and external factors key to facilitating or inhibiting the functions of this science department PLC and its efforts for school-based science curriculum change. *Internal factors* were defined as the structures and policies, individuals and groups within the middle school boundaries that influence curriculum changes. *External factors* were the structures and policies, individuals and groups including the social, political, economic, and environmental factors outside the boundaries of the middle school setting that influence curriculum changes.

Evidence of the influencing internal and external factors were identified through the collaborative discussions, reflections, and surveys taken by the PLC science teacher participants, and therefore represent the factors identified by the participants and perceived to most influence the science departments PLC's efforts at school-based science curriculum changes. Each factor will be discussed in following sections.

Internal factor—Middle school administrative support. Administrative support is not only key but also a requirement of successful PLCs—thus the dimension of *Shared and Supportive Leadership*. Due to the combined efforts of the upper levels of middle school administration and the science department chair, administrative support and shared leadership facilitated the efforts of the science department PLC. As one participant explained, the science department chair both supported the science department efforts and sought department collective decision making to enact curriculum changes:

> The department head is extremely open to the teacher's suggestions and input. The department head encourages and seeks out members' opinions and bounces ideas off the members. I feel I have a role in the decision making process as a member of the department. (Open-ended Reflection, Post-PLC 2, 2013)

The department chair made clear that the administrative position was to support the department PLC in its efforts towards school-based curriculum changes that led to improved student learning outcomes. The administration encouraged, supported, and appreciated the work undertaken by the science department PLC. "Bottom-up" curriculum development that was proximal and appropriate to the district and school culture was supported and valued in the eyes of the middle school administration. This supportive administration display facilitated a driven science teacher PLC with full encouragement for their change efforts. As noted earlier, the science administrator was in this case study both science department head and a science grade-level teacher; this close relationship between the administrator and science teaching in the middle school may have contributed to the high levels of support on behalf of the administrator and trust on behalf of the department members. As well, the science adminstrator made conscious efforts to involve the science PLC members in a collaborative dialogue for group decision making and PLC direction, as indicated in the following excerpt:

> Administrator: Okay, all right, so as I have said this *tuning protocol* isn't going to work properly as it is, because of the new and unique way we will be using it.... I just want to brainstorm how "we" think the best way to proceed is… (Transcript PLC 1 - Meeting 3, 2011)

The science PLC members took ownership of the PLC as shown by suggestions of improvements to the protocols and the planning of "next steps" without a thought of checking with administration first, as noted by the researcher in field observations. Leadership was handed over to the PLC and its members who fluidly shared the responsibility of decision-making through collaborative dialogue and cooperative solution designs.

Internal factor—Supportive relationship development. The *Supportive Conditions: Relationships* dimension revealed the importance of the PLC department member participants' interpersonal relationships as an influencing internal factor. Supportive relationships were demonstrated through positive and encouraging dialogue and discussion that reflected positive attitudes regarding the PLC process, other members, and the vision and PLC purpose. For the collaborative group to tackle the complicated and frustrating topic of school-based science curriculum change, it was necessary to secure a sense of mutual respect and solidarity. Protocols and strategies needed to be in place to encourage and foster such relationships and interactions, and to be a means for critical analysis and both positive and negative feedback to be received with trust. In the Post-PLC 2 (2013) reflection questions, one participant explained:

> It was of great value to be able to collaboratively look at the different grades' and teachers' curriculum to discuss, analyze, and reflect upon our current curriculum scope and sequences in the middle school science department. The discussions were respectful, insightful and valuable to the structure and evaluation of our curriculum. The process was essential to the departmental goals of curriculum improvements.

The individual members engaged in critical and collaborative discussion utilizing the *Tuning Protocol,* which provided a flexible structure where each member was heard, positive and reflective opinions were valued, and consideration occurred in a respectful manner. The high frequency of member communication, interaction, and feedback supported the development of the interpersonal relationships and trust necessary to challenge continuously and come to communal agreement on the science department PLC's shared vision and value. This is seen in the excerpt below, which highlighted the trust, interchange, critical analysis, awareness, and reflection available to the participants through the PLC (Transcript PLC 1 – Meeting 3, 2013):

> Teacher G: I think the first thing we need to do is to define, to have the eighth grade define for us what they see their concerns are regarding their topics, their scope and sequence. Like what is the issue that eighth grade has. Because we all have issues, you know? It's nothing to be ashamed about. We all have issues. What are the issues on the grade eight level?
>
> Teacher K: My concern is on I think, we all have a bit too much content and we all sort of self-removing things, and I don't think we're consistent on what we're removing….
>
> Teacher M: Am I hearing you correctly that the issue you see is too much content to be cut?
>
> Teacher I: My concern is my class might be getting farther away from everyone else's, to a point where it could be an issue.

Teacher J: We're self editing what we're taking out, for the most part. I think we take out some things that are the same but then we all have personally decided what's worked for our class. That's my concern.

Teacher M: Sounds like having some outside eyes might be helpful in terms of what to remove in order so that it might be a little bit more consistent. Your thoughts?

Teacher L: Yes…I think those decisions are resulting in us moving in different directions. Which, without saying, is going to result in four very different experiences, I think.

This exchange represents the true nature of the PLC. These teachers were able to share, within a safe and constructive conversation, a critical analysis of the eighth grade science curriculum. Within the exchange, teachers expressed their struggles, fears, and needs. They were guided and clarified by the facilitator to see that, although expressed in different ways, the major issue within the grade level was a common one. The conversation allowed for grade-level awareness of their common issue of too much content and the constructive review that resulted in identifying the curriculum issue of inconsistency. The internal factors necessary for such an interchange to occur within the science department PLC were generally identified by the *Supportive Conditions: Relationships* dimension. The PLC had to build trust between members and trust in the PLC process in order for supportive relationship development to take place.

The *Leadership* and *Relationship* dimensions highlighted the setting and opportunity for collaborative dialogue that was encouraged and supported by the administration as it sought the teachers' critical analysis of the current state of the middle school science curriculum. The overwhelming result was the department's recognition that while a solid science program was in place, curriculum change and adjustment were needed to address areas of weakness, disconnect, over-detail, and current developments in science teaching and learning. In this case, the awareness of needed reform was a positive factor for the function of the vision of the science department PLC and efforts, as seen in the following excerpt (Transcript PLC 1 – Meeting 2, 2011):

> Teacher B: So we are all willing to look at this and say what can we do to make this better, better not necessarily for us as teachers, but yes for us as teachers, but firstly for the kids?
>
> Teacher G: I'm willing to change whatever in order to support or to foster to do whatever we need to do in order to get them [students] to have good, wait, excellent experiences in learning.

Internal factor—Supportive structure and resources. Structural supports reflected the time allotted and available, communication procedures, the proximity of the teachers to each other, the size of the PLC, availability of necessary resources, funding, and professional development opportunities available to the members of the science department PLC.

Time was perceived as both a positive and an inhibiting factor to science curriculum changes through the department science PLC model. Appropriate time was necessary for teachers to work together, share information, and reflect on teaching and learning improvements. As one PLC member reflected in the Post-PLC 1 reflection (2011), "It is through the science PLC that we [the department] have had the time to reflect on these change possibilities and opportunities; before the PLC I would not have agreed with these statements." Members recognized that the PLC was able to provide collaborative opportunities and critical analysis of curriculum not normally available to the science department members and never as a whole department. In this way, the time within the PLC was essential to obtaining the goals of school-based science curriculum changes desired by the PLC. But even with the PLC, the members found that curriculum changes required huge chunks of time and collaborative efforts from individual members, grade-level teams, and the department as a whole. The PLC meeting in this sense could not provide all the time needed to design and create complete school-based science curriculum changes. The PLC members recognized that more time would be needed: “Not enough time spent with team opportunity to apply shared learning and results—I would love more of these opportunities!” (Post-PLC 1, 2011). As well, due to the size of the building and differences in teacher preparation times, the teachers felt it was difficult to meet during the school day. As voiced by one participant: “The building makes it hard to meet with teachers outside my building for work during the school day” (Post-PLC 2, 2012). Time therefore both facilitated and impeded the work of the science department PLC towards curriculum changes and improvements.

The resources provided by the school to support the science department PLC were essential to supporting the functions and outcomes of the PLC goals: “Our district has done a great job of providing us with the support and acknowledgment needed to work towards of our goals of middle school science curriculum improvements” (Post-PLC 2, 2012). Funding in the form of professional development and summer work was a facilitating factor in the forward momentum of school-based science curriculum change development and improvements for this PLC. Teachers were able to work in both grade-level groups and cross-level groups to enhance science skills and practices, common rubrics, curriculum flow, inquiry opportunities, and curriculum changes. The work completed over the summer was essential to the final outcomes of science curriculum changes and improvement made by the science PLC as PLC 2 proceeded based on the results of the summer work improvements.

External factor—District administrative support. The respondents viewed district administrative support as working within the school district, but not within the middle school building. As the superintendent of schools, assistant superintendent, and board approved the science department PLC and its goals of science curriculum change improvement, the external administration support was viewed as facilitating the efforts of the PLC. Science funding could be utilized to enhance the efforts of the PLC. Therefore, the speakers who were invited (the science education professor and local science department teachers) directly informed the science department PLC members on current science education trends in science thinking and learning. Teachers were able to utilize the school's *GoogleDocs* account to share curriculum information between teachers and grade levels. A science classroom was available for PLC use after school with Internet access, smart board, and projector, so the science PLC could utilize the entire World Wide Web offerings. The resources provided by the support from upper administration were essential to supporting the functions and outcomes of the science department PLC goals.

External factor—District goals. School district policies, practices, and goals influence the breadth and depth of curriculum topics and the manner and focus of lesson and activities in the classroom. Yet the district goals are developed outside of the middle school and are meant to encompass the entire district—thus, the external identification. District goals were found to overall facilitate the school-based science curriculum change efforts, although they complicated the change efforts as well. Evidence was found in teacher discussions and reflections in the *Leadership* and *Supportive Conditions* dimensions.

Reflections and discussions revealed that in general, the district goals impeded the developments of the science department PLC efforts at school-based science curriculum changes. The school district was devoted to high expectations and achievement levels for all students, with a focus on critical and creative thinking, 21st century skill development, and assessments that reflect and inform goal attainment. With all the district expectations the science department found it frustrating to incorporate district requirements with departmental goals of science curriculum changes. The exchange below from Transcript PLC 2 – Meeting 3 (2012) is from a PLC participant conversation that outlined the struggle the teachers had when considering the value and importance of incorporating the district goals into a middle science curriculum while trying to balance state standards, NGSS, department goals, and district goals for the ultimate goal for high levels of student science learning outcomes.

> Teacher E: …There's a lot of frustration expressed when we're having these discussions…for example, the concepts of teachers pushing kids to go beyond, to go and think and reason through problems…but then who does that upset? It upsets the kids because they're not succeeding. It upsets of the parents because their kid is not succeeding. It frustrates the teacher because the teacher is struggling to lead kids to higher levels which is a process…so it's like, it's this bizarre back and forth between yeah, you want to push them…you want to challenge them…you want to do that and simultaneously, it's all tangled together…
>
> Teacher F: It's between what's right and what's easy or makes the most sense for all involved, kids, teachers, parents, tests, sometimes with eighth grade we have a real struggle and debate about it.
>
> Teacher E: That's a point we are making as a group.
>
> Teacher I: The education for the future—teach all content but not too much and be sure to tie in technology, critically and creative thinking, common core…. All are important, all I believe in, but the struggle is how realistically does this translate into the curriculum and pedagogy of a single school year?

The district goals were a complicating factor; although the district supported curriculum changes that reached towards the district goals this in turn complicated the efforts of science curriculum change by the science department teachers.

Key Findings

This research study set out to document the development and evolutionary effects a PLC model could have on a middle school science department engaged in school-based science curriculum change efforts. Overall, results indicated that the design and function of the science department PLC meetings encouraged and developed the positive characteristics of successful PLC dimensions. Dimensional findings indicated that the two-year science department PLC allowed for the sustained development of shared leadership, PLC vision, new learning, knowledge application, shared personal practice, and the supportive conditions necessary to maintain PLC structure and participant relationship development. Protocols were found essential to the process and progression of the science department PLC. In particular, the application of the *Tuning Protocol* during PLC meetings set a norm of collaboration, critical analysis, and supportive conditions through the protocol routine. Therefore, the research findings identified the science department PLC as a unique interface that provided the means and opportunity for the science teachers to contextualize their specific science curriculum change challenges within the larger context of school, community, and educational issues. Through a science department lens, the PLC *actions* and *outcomes* led specifically to science department curriculum changes that were congruent with, yet not dictated by, district, state, and community desires. This highlights the uniqueness of what the science department PLC offered to the department: the means to consider and engage internal and external influences to science curriculum changes without being dictated by such factors. This was further supported by the evolving science department's PLC vision statement that, while functioning within the larger school district, remained separate and unique to the science department's desires for science curriculum change. The iterative manipulation of the vision statement provided a flexibility, meaningfulness, and buy-in to the vision, thus maintaining its position as a guiding direction for the science department PLC. Overall, the PLC was found not to solve problems, but to serve as a means to understand and explore science curriculum change issues. The results support the conclusion that the PLC provided a unique opportunity to discuss, analyze, critique, learn, reflect, and collaborate; in that sense, the PLC facilitated the science department's progression towards school-based science curriculum changes.

CHAPTER 5: DISCUSSION

At the heart of a PLC is the notion of a "community" that is collaborative, focused on learning, and results-oriented. Bolam et al.'s (2005) research and definition of a thriving PLC stated, "an effective professional learning community has the capacity to promote and sustain the learning of all professionals in the school community with the collective purpose of enhancing pupil learning" (p. 145). Within the PLC, members, while bringing their individual experience, construct knowledge and decisions through their collaborative interactions working towards a common goal. In this lens, PLCs link directly to constructivism, according to Hunt (2009), by aligning to principles important to constructivist learning theory. Further review of contemporary theorists' understanding of community functions and PLCs (Hipp & Huffman, 2007; Hord, 1997; Hunt, 2009; Stoll et al., 2006; Westheimer, 1999) supported the five dimensions essential to successful PLCs:

1. Shared and Supportive leadership
2. Shared Values and Vision
3. Collective Learning and Application
4. Shared Personal Practice
5. Supportive Conditions

The research framework therefore exploited this notion of using the five dimensions within a shared science educator community whose members were interconnected by a common value or vision and collectively working towards school-based science curriculum changes. The five dimensions of successful PLCs were found essential to the development, function, and progression of the science department PLC. As well, the dimensions worked together to soundly balance and support the progression of the PLC as it worked towards its goals.

With the proper support and structure in place, the science department PLC was able to progress, aligning its *actions* and *outcomes* with the vision and goals defined by the department. The PLC was the tool providing the ability to take science departmental *action*s towards the *outcomes* of science curriculum change improvements, with the consideration but not the dictation of the larger school community and state agendas. Figure 13 displays the interconnections between the science department PLC's *actions* and *outcomes*.

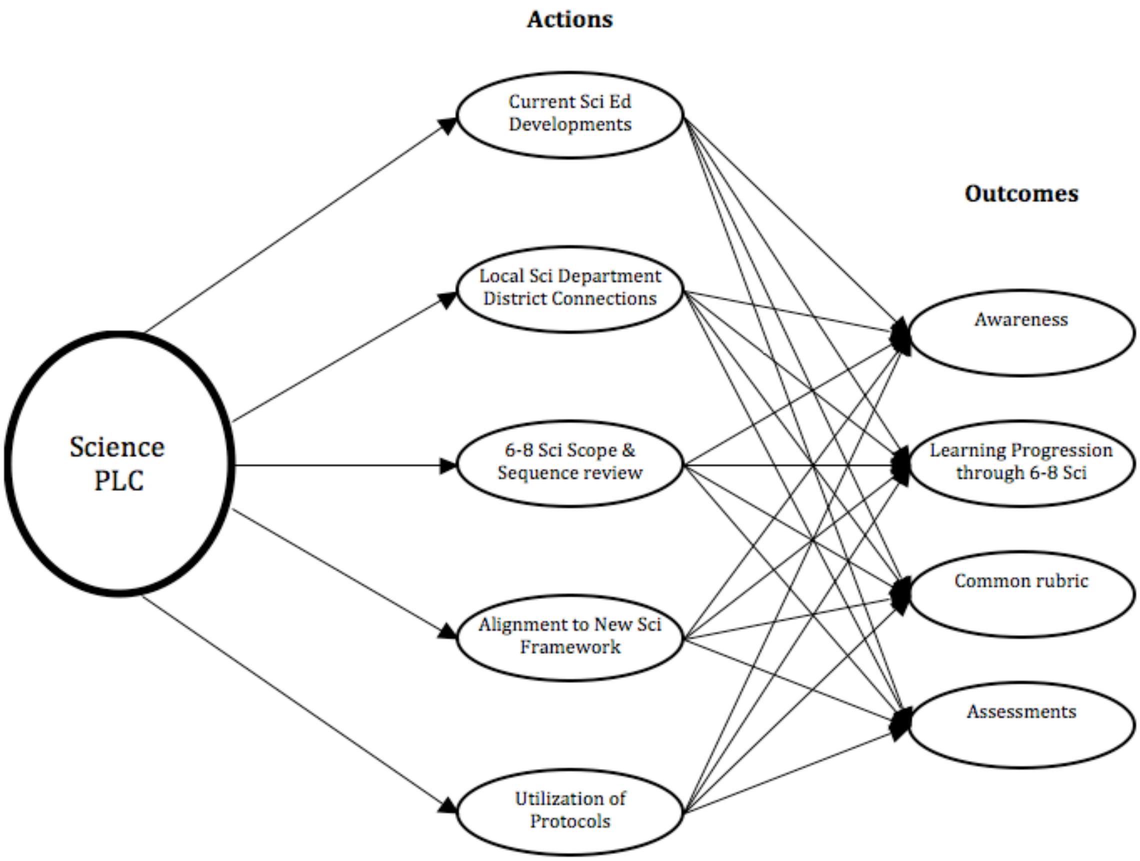


Figure 13. Interconnections Between Science PLC Actions and Outcomes

Thus, a PLC used at the middle school science department level allowed for a focal departmental lens to be applied to the structure and function of the PLC. As Figure 13 displays the science PLC process, procedings, and results directly aligned the PLC *actions* to *outcomes* driven by the science department towards science curriculum change.

The PLC, by centering on the students, was able to internally connect teachers, administrators, science curriculum changes efforts and student-learning outcomes by using the PLC model procedures and structures for the science department's effort. As well, the PLC allowed for the department members to consider external influences like district and government policies, standards and assessments, and school culture and community. Each internal and external factor was found to have an influencing role on science curriculum design at the middle school level and therefore impacted the PLC procedures and student learning outcomes. Figure 14 visually displays the various interactions and influences between the separate influencing factors, both internal and external, while maintaining the position of the PLC within the school structure.

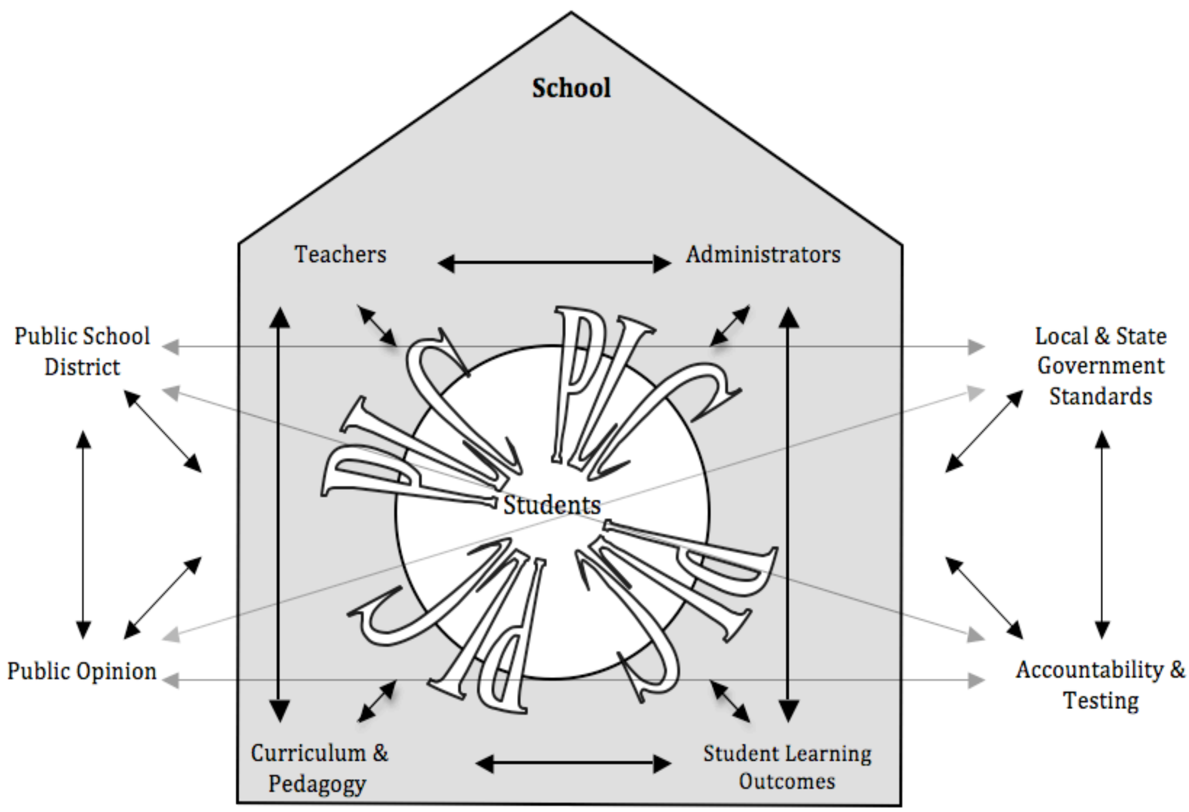


Figure 14. Position of the PLC Within the School System, Displaying the Influencing Internal and External Factors

The PLC functions within the structure of the school, and therefore school culture, with the main focal point being the students. Within Figure 14 the arrows display the interconnected and interwoven curriculum influences within the school system. Understanding those influences and the position of the PLC within the interconnections can show the means by which the science department PLC was able to enact science curriculum changes (Appendix I). The PLC worked to consider the influencing factors while maintaining a path of science curriculum change directed by the PLC participants. Although each factor continued its individual influencing role, the PLC's unique and protected position worked to provide the opportunity for the science teacher PLC participants to improve science teaching and student learning while considering science curriculum change within the context of all the factors. Because the factors were all connected via the science curriculum influence as part of the school system, the PLC teacher participants found that their curriculum change efforts considered these factors but were not dictated by those considerations. The science department PLC was therefore a unique interface for the science department. It was the position of the science PLC within the school that allowed its members to experience all influencing factors, while maintaining the lens of science curriculum change.

Bolam et al. (2005) proclaimed that PLCs are "an idea well worth pursuing as a means of promoting school and system-wide capacity building for sustainable improvement and pupil learning" (p. i). This research used a PLC for science education change; the data and findings showed that the community of science teachers and administrators collectively worked towards enhancing the science learning experience of students through the collaborative understanding, design, and implementation of school-based science curriculum changes.

Connections to the Literature

The current educational reality is one of reforms, 21st century skills, high-stakes testing, accountability, new standards, and common core curricula. In this constantly churning and perpetually changing climate of education, teachers and departments must make sense and balance incentives, policies, standards, and testing into meaningful, proximal pedagogy and curriculum that achieve school, state, public, and governmental goals while reaching student learning outcomes. The support needs of departments and teachers to maintain voice within these efforts inspired this research design. With the application of a PLC model, this research aimed to document the development and evolution of a middle school science department PLC engaged in school-based science curriculum change. The research addressed the previously unexplored coupling of PLCs, bottom-up school-based science curriculum changes, and science teaching and learning.

The emerging themes and key findings of this case study do, however, build on the body of contemporary literature on PLCs. For example, the application of the PLC model to a middle school science department aligns and relates to Stoll et al.'s (2006) claim that "if the community is to be intellectually vigorous, members need a solid basis of expert knowledge and skills, strongly emphasizing the professionalization of teachers' work through increasing expert knowledge" (p. 232). The science department members represented experienced science knowledge in their particular grade-level topics. Interactions between grade-level teachers and the invitation of expert speakers offered further science knowledge access, thus maintaining and encouraging intellectual vigor.

Stoll et al. (2006) added that “Professional learning is widely believed to be more effective when it is based on self-development and work-based learning” (p. 232). The science department PLC’s actions and outcomes were department-developed and driven, dedicated to teacher comprehension for the purpose of enhanced student science learning. Thus, the science department PLC was self-driven and work-related as all discussions, actions, and outcomes revolved around science teaching and learning issues, developments, and changes.

The learning that occurred in the science department PLC was distinctly collective (King & Newman, 2001) or situated in group learning. This situated community and group learning aligned with Pella’s (2011) findings that learning in a PLC is a process of social engagement or community participation of practice due to the interactions in and across the community and therefore involving constructivism, situated cognition, and social learning theory. The community learning that occurred through the actions of the science department PLC was the result of the interactions, collaborative dialogue, discussions, and critical analysis of presented information. Those actions of collaboration led to communal understanding and distinct PLC outcomes. Such organizational learning is supported and described through social learning theory (Smylie, 1995) and organizational learning research (Senge, 1990). Further support is found within Mitchell and Sackney’s (2000) descriptions of PLC learning, which occurs through an active deconstruction of knowledge via analytical practices and then a re-construction of knowledge through collaborative learning with peers.

The reasons the science department PLC members were able to interact successfully as a community of peers was in part due to the support and distribution of leadership. PLCs require the active support of leadership for sustainability and teacher buy-in; therefore the role of principals and administrators is essential:

> Set conditions for teacher community by the ways in which they manage school resources, relate to teachers and students, support or inhibit social interaction and leadership in the faculty, respond to the broader policy context, and bring resources into the school (McLaughlin & Talbert, 2001, p. 98).

PLCs are most successful work in cases where principals and administrators work together with teachers towards PLC goals (McLaughlin & Talbert, 2001; Mulford & Silins, 2003). The PLC literature recognized the importance of distributing leadership to encourage "workplace responsibility" and "the reciprocal actions of a number of people" (Gronn, 2003; Spillane, 2006) in order to work towards the PLC collective vision. Therefore, the PLC must be supported by an administration that is willing to take part in PLC proceedings without overtaking or running the PLC. The science department PLC was an expert example of such a situation in that the science administrator as a PLC participant supported PLC proceedings while also encouraging dispersed leadership through the *Tuning Protocol*.

Once established and supported, the PLC must continue to develop the five dimensions essential for successful PLCs (DuFour, DuFour, & Eaker, 2008; Hipp & Huffman, 2010; Hord, 2004). Through meeting protocols and continuous reflection, the science department PLC encouraged and manifested increased dimensions of successful PLCs. These dimensions included the development of relationships of collaboration and trust, as outlined by Bryk and Schneider (2002); the managing of structural resources such as time (Stoll, Fink, & Earl, 2003) and space (Hargreaves, 1994); the development of a shared and common vision (Andrews & Lewis, 2007); and the opportunity for shared personal practice (Hord, 2009).

As seen, the research described in the literature thus far focused on the practical benefits of PLCs on teacher learning in the context of a PLC (Dallas, 2006; Hashmi, 2011; Hord, 2009; Linder, Post, & Calabrese, 2012; Mundry & Stiles, 2009; Pella, 2011; Schmoker, 2005; Stoll et al., 2006) or the role of PLCs in school change accomplishment (Giles & Hargreaves, 2006; Hipp & Huffman, 2010; Huffman, 2003; Lardner & Malnarich, 2008; Morrissey, 2000; Stoll et al., 2006), but not on empirical evidence of the effects PLCs could have on the specific context of science departments and school-based science curriculum change. The emerging findings and themes of this case informed the literature as well as the application of PLCs for use by science departments that are exploring school-based science curriculum changes.

Interpretations of a Science Department PLC

Study findings indicated the PLC model was successfully applied and utilized by a middle school science department in its efforts at science curriculum changes. The manifestation and positive evolution of the five dimensions of successful PLCs over the research time pointed to the ways in which the PLC model was used by the science department for science curriculum change efforts. The science department PLC utilized the supports from the administration and dispersed leadership to explore and critically review science teaching and learning developments. The PLC vision focused the science PLC procedures on the track of science curriculum change for enhanced student learning experiences. The PLC process and protocols encouraged and provided the opportunity for sharing personal practice, new science learning, and application with the collaboration and reflection of the PLC members. Finally, the supports put in place, both structurally and interpersonal, sustained the PLC and its developments over time. Thus, the five dimensions of successful PLCs were applied to a science department PLC and used specifically to explore science teaching and learning for the purpose of increased science learning outcomes. Maintaining the science focus of the PLC's efforts and actions was the PLC vision. Because the vision was designed by and for the science teacher participants, the theme of science curriculum change through science teaching and learning was preserved in the face of all internal and external factors encountered by the PLC. The resultant actions and outcomes of a middle school science PLC was shown to provide a unique opportunity and forum for science teacher participants to conceptualize their goals of science curriculum change within the larger context of school community and educational issues. Therefore, the research findings demonstrated how the science department PLC's developmental process, protocols, design, dimension development, characteristics, actions, influences, and outcomes supported and informed the school-based science curriculum change efforts of the middle school science department. It was the opportunities provided by the science department PLC that allowed the science teacher participants to engage in collaborative discourse and critical reflections that led to the learning and application of new science knowledge for middle school science curriculum changes. The findings have compelling implications for both science educational research and schools looking to support teacher and departmental efforts at curriculum changes that are proximal and bottom-up.

Therefore, the "big picture" interpretations that emerged from the middle school science department PLC case study presented a unique perspective on PLC application that has not been previously identified within the literature. A PLC model, while providing professionals the opportunity to engage in learning, discussion, and application of new knowledge, becomes a unique science teacher exploratory tool when applied to a science department. A science department PLC instead provided a professional science forum where middle school science teachers were exposed to presenters and experts of science teaching and learning. The collaborative discussion and group learning revolved around science education and science curriculum changes. With the support of the science PLC, the science teachers explored new science standards and discussed their effects on student science learning within their own classrooms, according to science perceptions within school culture and community. Science teachers worked in grade-level groups to design science curriculum changes, which were presented to the PLC for critical analysis and reflection. The work of the science department through the PLC led to outcomes that had never before been attainable to the science department: common science middle school rubrics, scope and sequence alignment, and local science assessment developments. A science PLC provided an interface not previously available to science teachers to engage in the collective learning and application of new science teaching and learning knowledge, and the development and application of new science teaching and analysis of school-based science curriculum changes. A PLC in its more traditional and general use would not have provided the unique opportunity for science teachers' knowledge growth and science curriculum change efforts by a single science department at the middle school level.

Implications of the Science Department PLC

The implications arising from the research findings and interpretations present a variety of possible applications to PLC models, school departments, and science curriculum change efforts.

As stated earlier, this case study setting was a suburban, public middle school containing grades 6-8, with between 1,000 - 1,200 students per year and over 100 employees and staff members. The middle school science department consists of 12 middle school science teachers. Of the initial 11 participants in the PLC, 10 participants completed the entire study ($N = 10$). Thus, to be applicable beyond this study's context, the following suggestions are made.

Initial implications point to the importance of identifying a department that may benefit from the PLC process and to a facilitator willing to organize the logistical, structural, and functional aspects of the PLC. A department demonstrating a willingness to change, work collaboratively and outside of the school day is opportunistic for a PLC. A successful PLC facilitator is one willing to coordinate with administration for needed resources and structural support; organize dates, times and topics for the PLC meetings; participate in PLC training so as to properly support the development of the community of learners; organize expert speakers as necessary; and facilitate PLC meetings without leading or running PLC meetings. A PLC facilitator must believe in the community process of the PLC and the ability of the community to come to new understanding through the interactive and collaborative processes of teamwork, dispersed leadership, critical review and reflection.

To utilize the PLC model successfully for science curriculum changes, small schools may need to pool their science teachers, thus creating a science PLC of K-12 science teachers. Another option is to design a science teacher PLC that consists of science teachers from various local school districts; this would allow for the critical mass necessary to create a community of science teachers collaborating their experiences and working towards curriculum change goals.

Both the qualitative and quantitative data indicated that within this case study, the science department members exhibited positive characteristics of the dimensional aspects of successful PLCs prior to the initiation of the PLC. This implies that the science department brought its previously developed collegial relationships to the science department PLC. Yet through the process of the PLC and the application of the *Tuning Protocol*, those collegial relationships evolved into interactions of a more critical and collaborative nature. Thus, the use of a science department with previous experiences and rapport together was beneficial to the PLC's process and proceedings. This is not to say that a science teacher PLC cannot function unless previous relationships are present; thus, the following suggestions have been made for those schools lacking a teacher rapport.

In a situation where teachers do not have or cannot display the positive aspects of the PLC dimensions, the *Tuning Protocol* can be used to set a routine of interaction, participation, and sharing. The application of the *Tuning Protocol* can encourage collaborative analysis and dynamic feedback within a set and familiar protocol, making collaborative discussion available even to participants who are not familiar with each other. As well, the *Tuning Protocol* is flexible enough to be tweaked to a group's needs, extending or reducing the pieces of the protocol in order to fit the needs of the group and the task.

Research findings showed that the length of the PLC influenced the development and manifestation of the PLC dimension. Each of the individual dimensions increased positive aspects over the PLC time, with the final PLC 2 reflections displaying the highest levels of positive attributes for all dimensions. Therefore, the implications suggest the need for a PLC to be longitudinal in its goals and meeting schedules. PLCs require the careful design and consideration of meeting protocols and schedules in order to include and engage the critical dimensions for successful PLCs. It is suggested that any department designing a PLC utilize the protocols found in this study. The flexibility of the protocols allows for the application to a variety of school and department situations.

This PLC used a science educational lens while working towards its goals of science curriculum change. Because these efforts were the results of the middle school science department, all work was proximal, incorporating the school/district goals, culture, community, and climate. While making decisions solely for the science department, the participants were science teachers sensitive to the larger developments and changes occurring within the science and educational community. The implication thus is that a PLC for a science department allows for the unique opportunity of the participants to work towards science goals within the larger context of the school and educational challenges. In addition, the findings showed that the science PLC provided a safe and protected environment for the participants to engage in discussion and consideration of the internal and external factors influencing curriculum efforts and changes. It is recognized that each case and department is unique in its goals and influencing factors, but the PLC model does provide the forum for change motions to be considered, discussed, and analyzed for appropriateness and sustainability. Therefore, other departments considering curriculum change should consider the application of the PLC as a positive tool/strategy when working towards curriculum goals that must consider, but not be dictated by, the larger school, district, and educational context in order to be relevant and sustainable.

The science department PLC did not solve problems; instead, it provided the time, place, resources, procedures, interactions, and data to explore and understand science curriculum problems and possible steps towards change. The implication is therefore that the PLC acted as a tool or strategy to investigate, tackle, and work towards collaborative and collective solutions to departmental concerns of curriculum and change. Thus, the true and unique value of this process was in the collaboration protocols and resources it offered to a department working towards curriculum changes. Schools and departments tackling such issues would do well to consider a similar application of a PLC model as a means of exploring and working progressively towards change motions.

Teacher Agency and Curriculum Change

The scope of this research study focused on developing a science department PLC to support science teacher efforts towards school-based science curriculum change. Throughout the science PLC process it became evident that there was tension between developing science curriculum and the science standards (which included the state standards and the *Next Generation Science Standards*). Although teachers struggled with the incorporation of standards into a cohesive and proximal curriculum that would make sense for their students and school community, curriculum changes were achieved. This leads to the question of what curriculum changes were achieved and how the science department PLC supported the science teachers in their process of curriculum change efforts.

As outlined by the identified science PLC outcomes in Table 8, the middle school science teachers in PLC year 1, first documented their grade level science scope and sequence (Appendix I:1) as a starting curriculum point. After considering the presented speaker information on the changed in science education teaching and learning developments as well as local district curriculum changes in light of the new ways of learning and teaching science, the science department PLC teachers began to analysis the areas of necessary improvement in their own curriculum and grade levels. The science PLC teachers identified science practices and scientific and engineering learning progressions to be the most beneficially areas for skill development and science curriculum change. The middle school science teachers used the PLCs' newly created middle school science skills common rubric (Appendix I:2) to realign all their laboratory activities for scaffolded progression through grades 6 – 8 and for the cohesiveness of lab format and skill requirements. The science teachers then identified scientific and engineering learning progressions (Appendix I:3) in the science curriculum and aligned specific lessons, labs, projects and activities to support skill development throughout the 6-8 middle school experience (Appendix:4). Finally teachers realigned and tweaked their curriculum to further support the *Framework for K-12 Science Education* and for a more authentic science learning experience by realigning their curriculum topics, scope and sequence to that of the *Framework for K-12 Science Education* (Appendix I:4).

The changes made to the middle school science scope and sequences were found, in the words of the science departments PLC teachers, to be "tweaks" to the curriculum instead of completed curriculum overhaul and realignment. This decision by the science teachers to tweak their curriculum to maintain alignment to the state standards while considering the movement towards the *Next Generation Science Standards* relates back to the tensions between standards and curriculum. Given the context of teacher perceived control or there lack of, over their curriculum, the teachers felt they were inhibited by the requirements of content in the standards. This perception of inhibition was attributed to student assessments, which directly affected teacher accountability, as the tests were aligned to the state standards. Therefore teachers felt they could maneuver within their curriculum but they were stuck with the content standards. Teacher expectations of controlling aspects of their curriculum through the PLC process, lead to the middle school science curriculum change tweaks.

The above discussion reflects on teacher agency around curriculum and the role of the PLC process in teacher agency regarding curriculum. The PLC provided voice and opportunity for the science teachers to take control of their curriculum in light of new science teaching and learning developments as well as considering changing state and federal science standards. The science department PLC gave the middle school science teachers the opportunity and supports necessary to investigate new science teaching knowledge and the efforts such developments should and could have within their middle school classrooms. It is here that the science PLC provided the participants the professional capacity to take hold of their own science curriculum to ensure bottom-up and proximal curriculum changes.

Limitations and Recommendations for Future Research

This research collected data and findings which identified and described how the five dimensions of successful PLCs manifested and developed throughout a science department PLC; described the characteristics and outcomes of a PLC focused on a science department; identified both the actions and influences that facilitated and inhibited the science department's curriculum change efforts; and identified the internal and external factors influencing school-based science curriculum changes. As the findings, interpretations, and implications of this case study are encouraging when considering PLC application in the context of school-based science curriculum change, the limitations of the research must also be transparent for accurate result discernment. The following describes the major limitations of the research study and recommendations for improved and future research on science department PLC application.

The first research limitation was due to the nature of a single case study research. As this was a case study bounded within a particular school, subject, and time, generalizability was unsupported. Because the PLC members were specific to a particular science department, the methodology could not apply random sampling interpretations. Thus, the findings are specific to this particular case and this particular group of teachers; the findings do not represent the general science teacher population. Due to the small sample size and the familiarity of the participants, extreme measures were taken to protect confidentiality, therefore limiting data interpretation to general PLC participant trends; no individual tracking of member change and development over time occurred. Individual tracking of teacher growth and development through the PLC would have added further validation to the specific role of the PLC in teacher curriculum change knowledge and efforts. The science department members brought to the PLC their previous collegial relationships, thus influencing the initial PLC dimension appearances. Therefore, the initial high levels of dimensional aspects were not due to the application of the PLC; instead, these levels were a natural result of the science department members' previous interactions. All participants were subject to the same experimental treatment of the PLC and there was no control group for comparison. Examination of a science department involved in school-based science curriculum changes without the support of a PLC would allow for a better understanding of how the PLC process aided in curriculum change efforts.

Another limitation occurred as the surveys and reflections were completed at the conclusion of the PLC meetings. Perhaps explanations would have been expanded or altered if interviews were conducted at separate times. Finally, because I was both a research and a participant in the science teacher PLC, the study procedures and interpretations were subject to researcher influence and objectivity must be a consideration. Although multiple protocols and sources of validation were used to ensure accuracy and insight, there is always the chance that the researcher influenced the study procedures or that interpretations were not objective. Therefore, future studies should involve the same research procedures and data collection with the researcher as observer to confirm all interpretations and reduce objectivity complications.

Based upon the goals of this research and the identified limitation considerations, the following recommendations are offered to continue and expand the research goals by further deepening, informing, and enlightening the application of a PLC model for departmental curriculum change.

Recommendation 1. As this was a case bounded by time, subject, and school, this research should be repeated to confirm the use of a science department PLC as a tool to aid teachers and a department in efforts of school-based science curriculum change.

Such research could be expanded to a correlation study of science department PLC use in various school levels (elementary, middle, high, professional) and/or variant schools of student performance levels (high, middle, low, failing).

Recommendation 2. This research would be of further value if expanded for application to other subject departments engaged or undertaking curriculum change efforts. The employment of the PLC model to a single department has powerful implications for collective and productive dialogue that leads to teacher voice and collaborative decision-making. A process such as a PLC is one that has taken efforts to encourage member buy-in and dedication, member-designed changes, changes that are bottom-up and proximal, changes that are supported throughout implementation by the PLC members, and curriculum change efforts that have the potential for sustainability. Therefore, a comparative study of PLC use in different departments would be a powerful study with application to variant departments looking for a tool to support teachers and schools in curriculum change efforts.

Recommendation 3. The literature would benefit from the further study of the utilization of *Tuning Protocols* within departmental decision making and within PLC and other Learning Community situations. The *Tuning Protocol* provides a group with a routine of sharing and analysis; therefore, application of the *Tuning Protocol* without prior rapport would support PLCs and/or LCs struggling with mixed school participation. As well, *Tuning Protocols* work to disperse leadership, encouraging growth in leadership roles and leadership opportunity within PLCs/LCs. Thus, further studies on the use and application of *Tuning Protocols* to various types and sizes of PLC groups would benefit future PLC application.

Recommendation 4. The customization of a PLC for departmental use has the unique opportunity to capitalize on the departmental connections already forged within and between the department members. Research into the types of relationship development present before, during, and after the PLC may be of interest to constructivist research and further teacher group learning and knowledge attainment/application.

Recommendation 5. The structure of the PLC allows for a different kind of professional development (PD), which is better described as professional learning and application. The comparison of the sustainability of changes implemented through the PLC as opposed to that of PD situations may also be an informative development of teacher learning and supporting change/reform motions.

Recommendation 6. The PLC has the potential to evolve into a mentoring and coaching program specific to subject departments. Therefore, research on this application could be used for new teacher mentoring. It is recommended that an entire department as a PLC take on responsibility for new teacher development. The PLC could offer support, collaborative discussion, critical analysis, shared practice, and learning and application opportunities not normally provided to new teachers by the entire department. If it takes a community to raise a child, it may take a department to foster a new teacher.

Recommendation 7. Departmental PLCs as well can be used to forge connections with other school districts, professionals, and colleges to aid K-12 subject departments in their efforts to produce relevant curriculum that is standards-aligned, appropriately challenging, and useful for preparing students for the real and professional world. Therefore, it is recommended that research on PLCs making such connections in and between schools, professionals, and communities be conducted to further inform the literature on PLC application.

Final Thoughts

Considering the current challenges to reforming science education and the emerging perspectives on science teaching and learning (Duschl et al., 2007; Hurd, 1997), science educators find the alarming need for science curriculum changes that reflect contemporary educational developments, reform, and the requisites of developing 21st century students. The publics call for science curriculum reform is a reality, and to meet the demands, recent work in the science educational field has produced the *Framework for K-12 Science Education* (NRC, 2012) and the Next Generation Science Standards (NGSS) (Achieve, Inc., 2013). Although specifically not a curriculum, the *Framework* and NGSS are prime examples of a top-down standards initiative that schools and science departments will be responsible to translate and employ. Therefore, ensuring bottom-up curriculum development and proximal pedagogy in the face of top-down standards development is an immense challenge to science department teachers and school-based science curriculum change efforts. Needed is a way or means for teachers to maintain their voice and input through proximal pedagogical curriculum changes within their school communities. The barriers and continued struggles of meaningful and sustained school-based curriculum changes are palpable. Yet the findings of this research work to offer science departments a tool, which, if properly employed, has the potential of coupling, previously unexplored areas of PLCs, bottom-up school-based science curriculum changes, and science teaching and learning.

The purpose of this research study was to explore the potential application of PLCs focused specifically on a science department. Multiple sources of qualitative and quantitative data were triangulated to provide a comprehensive understanding of the manifestation and evolution of the five dimensions of PLCs, the characteristics and outcomes of a science-focused PLC, and whether the actions of a science PLC facilitated or impeded a science department's goal of science curriculum change. Evidence was found that through the actions of the science PLC meetings, the five dimensions of PLCs did manifest, increase, and evolve over time. With the increase in each of the five dimensions came an increase in the understanding and realization of the department's goals of science curriculum changes and the teaching and learning issues that ensued, as seen through the development and refinement of the PLC vision. It is recognized that the five dimensions of successful PLCs are in fact interconnected and dependent on each other for the progression of the PLC as a collective and collaborative whole. Therefore, it is essential that the five dimensions be a considerable portion of the development and planning stages of any PLC, to be continually reflected upon and evaluated by the PLC developer/facilitator/researcher. Direct results of the science PLC did assist the department's progression towards school-based science curriculum changes in the form of developed scope and sequence as well as curriculum realignments at each grade-level common rubric across grades 6-8 and alignment with the NGSS and curriculum changes.

The implications of this study are that a PLC focus specifically on a science department does, through the nature and actions of the PLC, aid in school-based science curriculum changes. Replication and continuation of longitudinal studies of departmental PLCs in various contexts should be investigated to determine whether the phenomena observed in this research study are generalizable across subject departments or are context-dependent.

The use of PLCs for the purpose of science curriculum change can contribute an essential tool to science departments that are searching for a means to explore, enact, and sustain school-based science curriculum changes (Keeley, 2009). The research as well has implications for scholars, practitioners, teachers, professionals, and community members in their understandings of the role and function PLCs have in curriculum development and educational reform/change movements. Outcomes of this research could be of use and value to any department facing school-based curriculum changes that are sustainable over time because of teamwork, dispersed leadership, and collaborative problem-solving techniques. Much work remains to be done in the realm of science education and science department PLCs, as this case study has shown, but this research offers a new tool and strategy to aid science departments in the process of science curriculum changes that are proximal, bottom-up, collaborative, and sustainable.

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APPENDIX A

The Tuning Protocol

THE TUNING PROTOCOL

Tuning Protocol

1. Introduction .... 5 minutes

- Facilitator briefly introduces protocol goals, norms, and schedule.
- Participants briefly introduce themselves (if necessary).

2. Presentation .... 15 minutes

Teacher presents.

- Context (what the students tend to be like, where they are in school, where they are in the year)
- Assignment or prompt that generated the student work
- Student learning goals that inform the work
- Samples of work (photocopies of written work, video clips)
- Evaluation format (e.g. rubric, test)
- Focusing question for feedback

Participants are silent.

3. Clarifying Questions .... 5 minutes

- Clarifying questions are matters of fact ("How many students will you have in this class?" "What kind of prior experience in this subject can you count on?") Save substantive issues for later. The facilitator is responsible for making sure that clarifying questions are really clarifying.

4. Examination of Work .... 5 – 7 minutes

- Participants look at the work, take notes on where it seems "in tune" with goals and where there might be problems; and (if appropriate, see Feedback section) write down warm and cool feedback, as well as probing questions. Participants focus particularly on the presenter's question.

5. Feedback .... 15 minutes

- Participants talk to each other about the work (pretending that presenter is not in the room), beginning with ways in which the plan seems likely to meet the goal, continuing with possible disconnections and problems. These don't need to be in tight sequence, but participants should always begin with some positive feedback.

  Some groups prefer to structure the session by beginning with 5 minutes of "warm" feedback (positive—"What are the strengths here?"), 5minutes of cool feedback (more critical—"Where are the gaps?"; "What are the problems here?"), and 5 minutes of "hard" or "probing" questions for the presenting teacher to consider.

  The facilitator may need to remind the participants of the presenter's focusing question.

Presenter is silent.

6. Reflection .... 5 minutes

- Presenter talks about what she has learned from the participant feedback. This is NOT a time to defend oneself (this is for the presenter and defending isn't necessary), but a time to explore further interesting ideas that came out of the Feedback section.

At any point the presenter may open the conversation to the entire group (or not).

7. Debrief .... 5 minutes

- Facilitator-led open discussion of this tuning experience.

This is from ***A Guide to Looking Collaboratively at Student Work*** by David Allen, Tina Blythe, Barbara Powell.

APPENDIX B:1

RTOP Form

Reformed Teaching Observation Protocol (RTOP)

Daiyo Sawada
External Evaluator

Michael Piburn
Internal Evaluator

and

Kathleen Falconer, Jeff Turley, Russell Benford and Irene Bloom
Evaluation Facilitation Group (EFG)

Technical Report No. IN00-1
Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University

I. BACKGROUND INFORMATION

Name of teacher ____________________ Announced Observation? ____________________ (yes, no, or explain)

Location of class ____ (district, school, room)

Years of Teaching ____________________ Teaching Certification ____________________ (K-8 or 7-12)

Subject observed ____________________ Grade level ____________________

Observer ____________________ Date of observation ____________________

Start time ____________________ End time ____________________

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

2000 Revision

p 1 of 1

Record here events which may help in documenting the ratings.

Time	Description of Events

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred				Very Descriptive
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3)	In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional knowledge

6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9)	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14)	Students were reflective about their learning.	0	1	2	3	4
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

Continue recording salient events here.

Time	Description of Events

V. CLASSROOM CULTURE

Communicative Interactions		Never Occurred				Very Descriptive
16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20)	There was a climate of respect for what others had to say.	0	1	2	3	4
Student/Teacher Relationships						
21)	Active participation of students was encouraged and valued.	0	1	2	3	4
22)	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4
23)	In general the teacher was patient with students.	0	1	2	3	4
24)	The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

Additional comments you may wish to make about this lesson.

Protocol Reference:

Sawada, D., Piburn, M., Falconer, K., Turley, J., Benford, R., and Bloom, I. (2000). Reforming Teaching Observation Protocol (RTOP). Technical Report No. IN00-1. Arizona Collaborative for Excellence in the Preparation of Teachers. Arrizona State University. Arizona Board of Regents.

APPENDIX B:2

Collaborative Evaluation
PLC Observation Protocol

Researcher: ______________________________
Place: _________________________________ Date / Time: ________
Number of PLC Participants Present: ___________
Purpose:

Guest Speaker Name:_________________________________

Expertise:

Presentation Purpose:

Presentation Introduction (duration ____):

Key Points of Presentation Body (duration____):

Presentation Closure (duration____):

Length of Presentation: _____

Session Background: Objectives of the meeting as stated by the presenter/ facilitator:

Session Activities Observed:
Check the activity observed during the session and fill in the total amount of time for that activity:

1. Discussion of prior PLC meetings and objectives, learning from previous session, or learning needs of participants ________
2. Small Group Work _______
3. Whole / Large group Work _______
4. Exploration of Materials _______
5. Participant development of questions and/or hypotheses ______
6. Experimentation and data gathering / documentation ______
7. Discussion / Sharing on findings ________
8. Sense making based on findings ________
9. Discussion of science department mission/vision _______
10. Discussion of science concepts in question _______
11. Identification of emerging questions ________
12. Discussion of application to science department ________
13. Other: __________________________________ ________

Observations Made During Meeting	**Additional Details Upon Audiotape Review**	**Reflective Notes**
Description of the Setting:		
Questions and discussions raise by PLC members:		
Interactions between PLC members:		
Interactions between PLC members and guest speaker:		
Description of activity preformed by PLC (content, nature of activity, what participants do, what presenter does, interaction):		

Engagement of Participants

To what extent did most or all of the participants in the PLC meeting do the following:

1. Engage in hands-on activities?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

2. Engaged in the small group discussion?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

3. Engaged in the large group discussions?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

4. Stay on task during the session?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

5. Interact with various members of the PLC?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

PLC Meeting Design, Content, Implementation

To what extent did the following occur:

1. The presentation was designed to address the objectives of the PLC.

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

2. The presentation encouraged PLC members to seek and value alternative solutions to their curriculum?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

3. The focus and direction of the meeting was determined by the ideas originating from the PLC members?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

4. The presentation promoted coherent conceptual understanding

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

5. Participants had a strong grasp of the major points and content inherent in the presentation

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

6. Connect to real world situational learning was evident?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

7. Participants were reflective in their questioning?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

8. Participants were involved in and given the opportunity to communicate their ideas.

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

9. There was a climate of respect.

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

10. Interactions encouraged conjectures, alternative solutions, strategies, and ways of interpretation?

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

11. Presenter acted as a resource person, working to enlighten, support, and enhance movement towards PLC mission.

To a Great Extent				Not at All	Not Applic.
(5)	(4)	(3)	(2)	(1)	NA

<u>Protocol References</u>:

Bracket, A., and Hurley, N. (2004). Collaborative Evaluation Led by Local Educators: A practical, print- and web-based guide. San Francisco: WestEd. Downloaded from: http://www.neirtec.prg/evaluation/PDFs/PreparingtoCollect2d.pdf

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APPENDIX C:1

Professional Learning Community Meeting Survey

Professional Learning Community Survey
(5 Minute Survey)

Directions: Please circle the number on a scale from 1-4, which best indicates your response to the statements. 4 indicates the most agreement and 1 the least.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

Reflection on Professional Learning Community (PLC)

1. Overall satisfaction with learning community experience.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

2. Satisfaction with the PLC meeting.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

3. The PLC meetings provide a forum for addressing science department goals.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

4. The PLC presenter(s) provide alternative views and solutions to the science department curriculum goals.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

5. The PLC provides the opportunity to analyze and critically evaluate ideas.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

6. The PLC presenters are educated, relevant, and useful to science department mission.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

7. The PLC provides the opportunity to work cooperatively and productively with others.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

8. The PLC helped me to develop connections with professionals working on or concerned with science education.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

9. The PLC has encouraged my understanding of issues with science curriculum change implementation and sustainability.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

10. I would recommend the formation of a PLC to other education departments.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

APPENDIX C:2

Professional Learning Community Survey
(Mid-Year and End of Year)

<u>Directions</u>: Please circle the number on a scale from 1-4, which best indicates your response to the statements. 4 indicates the most agreement and 1 the least.

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

Participation in Professional Learning Community (PLC)

***My participation in the Science Department PLC has encouraged*:**

1. A sense of belonging

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

2. My ability to share my opinion

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

3. My ability to be heard

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

4. My ability to analyze and evaluate ideas systematically and critically from different perspective

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

5. My ability to think of different ways to solve science department problems

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

6. My ability to work cooperatively and productively with others

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

7. My ability to effectively listen and reflect that understanding back to the PLC

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

8. My ability to interact with others and contribute to group discussion

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

9. My ability to put department goals of science change above my own personal goals and desires

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

10. My ability to argue my point of view respectfully and assertively

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

11. My opportunities to interact with various professions and presenters at PLC meetings

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

12. Interest in continuing working with the PLC

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

13. My ability to make science curriculum changes

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

14. The ability to make informed science curriculum changes

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

15. The quality of middle school science curriculum

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

16. Connections with the middle school

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

17. Connections with other professionals and experts outside of the middle school

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

18. Awareness of current science curriculum reforms and changes

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

19. The ability to connect to various out-side resources to support science curriculum

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

20. Opportunities to become involved science curriculum activities

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

21. Communication with community members

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

22. Communication between PLC members

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

23. Participation in department science curriculum changes

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

24. My ability to interact with people outside of the department regarding science curriculum

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

25. My understanding of science curriculum development

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

26. My understanding of student needs from the science curriculum

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

27. My understanding of science scope and sequence

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

28. My understanding of science literacy

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

29. My understanding of science skills

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

30. My understanding of the science department vision and mission statement

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

31. My knowledge of the issues facing science curriculum change

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

32. My knowledge of the issues facing students as science learners

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

33. My consideration of science standards

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

34. The adjustment of curriculum to necessities of modern science student

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

My involvement in the Science Department PLC has helped me to:

1. See connections among the science department goals and community goals

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

2. See connections between science curriculum change and student achievement

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

3. See connections between my personal beliefs regarding middle school science curriculum and current research on science curriculum

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

4. Better understand the needs for science curriculum change that supports student achievement

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

5. Apply what I have learned from experts to our department science curriculum goals

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

6. Put into practice the skills I am learning or have learned

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

7. Find support for lasting curriculum change

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

8. Become involved in the department goal of science curriculum changes

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

Professional Learning Community Meeting Presenters have:

1. Overall been helpful to the department vision and science curriculum goals

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

2. Aided in widening my understanding of science curriculum options and opportunities

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

3. Provided useful and relevant science education information

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

4. Facilitated interactions and discussions for the PLC

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

5. Broader my understanding of science curriculum change

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

6. Helped me to learn about current science curriculum research

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

7. Helped me to learn about available resources

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

8. Helped me understand community members science curriculum expectations

Strongly Agree	Agree	Disagree	Strongly Disagree
(4)	(3)	(2)	(1)

APPENDIX D

PLCA - R

Professional Learning Communities Assessment - Revised

Directions:
This questionnaire assesses your perceptions about your principal, staff, and stakeholders based on the dimensions of a professional learning community (PLC) and related attributes. This questionnaire contains a number of statements about practices which occur in some schools. Read each statement and then use the scale below to select the scale point that best reflects your personal degree of agreement with the statement. Shade the appropriate oval provided to the right of each statement. Be certain to select only one response for each statement. Comments after each dimension section are optional.

Key Terms:
Principal = Principal, not Associate or Assistant Principal
Staff/Staff Members = All adult staff directly associated with curriculum, instruction, and assessment of students
Stakeholders = Parents and community members

Scale: 1 = Strongly Disagree (SD)
2 = Disagree (D)
3 = Agree (A)
4 = Strongly Agree (SA)

	STATEMENTS	**SCALE**			
	Shared and Supportive Leadership	**SD**	**D**	**A**	**SA**
1.	Staff members are consistently involved in discussing and making decisions about most school issues.	0	0	0	0
2.	The principal incorporates advice from staff members to make decisions.	0	0	0	0
3.	Staff members have accessibility to key information.	0	0	0	0
4.	The principal is proactive and addresses areas where support is needed.	0	0	0	0
5.	Opportunities are provided for staff members to initiate change.	0	0	0	0
6.	The principal shares responsibility and rewards for innovative actions.	0	0	0	0
7.	The principal participates democratically with staff sharing power and authority.	0	0	0	0
8.	Leadership is promoted and nurtured among staff members.	0	0	0	0
9.	Decision-making takes place through committees and communication across grade and subject areas.	0	0	0	0
10.	Stakeholders assume shared responsibility and accountability for student learning without evidence of imposed power and authority.	0	0	0	0
11.	Staff members use multiple sources of data to make decisions about teaching and learning.	0	0	0	0

COMMENTS:					
	STATEMENTS	**SCALE**			
	Shared Values and Vision	**SD**	**D**	**A**	**SA**
12.	A collaborative process exists for developing a shared sense of values among staff.	0	0	0	0
13.	Shared values support norms of behavior that guide decisions about teaching and learning.	0	0	0	0
14.	Staff members share visions for school improvement that have undeviating focus on student learning.	0	0	0	0
15.	Decisions are made in alignment with the school=s values and vision.	0	0	0	0
16.	A collaborative process exists for developing a shared vision among staff.	0	0	0	0
17.	School goals focus on student learning beyond test scores and grades.	0	0	0	0
18.	Policies and programs are aligned to the school=s vision.	0	0	0	0
19.	Stakeholders are actively involved in creating high expectations that serve to increase student achievement.	0	0	0	0
20.	Data are used to prioritize actions to reach a shared vision.	0	0	0	0
COMMENTS:					
	Collective Learning and Application	**SD**	**D**	**A**	**SA**
21.	Staff members work together to seek knowledge, skills and strategies and apply this new learning to their work.	0	0	0	0
22.	Collegial relationships exist among staff members that reflect commitment to school improvement efforts.	0	0	0	0
23.	Staff members plan and work together to search for solutions to address diverse student needs.	0	0	0	0
24.	A variety of opportunities and structures exist for collective learning through open dialogue.	0	0	0	0
25.	Staff members engage in dialogue that reflects a respect for diverse ideas that lead to continued inquiry.	0	0	0	0
26.	Professional development focuses on teaching and learning.	0	0	0	0
27.	School staff members and stakeholders learn together and apply new knowledge to solve problems.	0	0	0	0

28.	School staff members are committed to programs that enhance learning.	0	0	0	0
29.	Staff members collaboratively analyze multiple sources of data to assess the effectiveness of instructional practices.	0	0	0	0
30.	Staff members collaboratively analyze student work to improve teaching and learning.	0	0	0	0
COMMENTS:					
	STATEMENTS	**SCALE**			
	Shared Personal Practice	**SD**	**D**	**A**	**SA**
31.	Opportunities exist for staff members to observe peers and offer encouragement.	0	0	0	0
32.	Staff members provide feedback to peers related to instructional practices.	0	0	0	0
33.	Staff members informally share ideas and suggestions for improving student learning.	0	0	0	0
34.	Staff members collaboratively review student work to share and improve instructional practices.	0	0	0	0
35.	Opportunities exist for coaching and mentoring.	0	0	0	0
36.	Individuals and teams have the opportunity to apply learning and share the results of their practices.	0	0	0	0
37.	Staff members regularly share student work to guide overall school improvement.	0	0	0	0
COMMENTS:					
	Supportive Conditions – Relationships	**SD**	**D**	**A**	**SA**
38.	Caring relationships exist among staff and students that are built on trust and respect.	0	0	0	0
39.	A culture of trust and respect exists for taking risks.	0	0	0	0
40.	Outstanding achievement is recognized and celebrated regularly in our school.	0	0	0	0
41.	School staff and stakeholders exhibit a sustained and unified effort to embed change into the culture of the school.	0	0	0	0
42.	Relationships among staff members support honest and respectful examination of data to enhance teaching and learning.	0	0	0	0
COMMENTS:					

	Supportive Conditions – Structures	SD	D	A	SA
43.	Time is provided to facilitate collaborative work.	0	0	0	0
44.	The school schedule promotes collective learning and shared practice.	0	0	0	0
45.	Fiscal resources are available for professional development.	0	0	0	0
46.	Appropriate technology and instructional materials are available to staff.	0	0	0	0
	STATEMENTS	**SCALE**			
		SD	**D**	**A**	**SA**
47.	Resource people provide expertise and support for continuous learning.	0	0	0	0
48.	The school facility is clean, attractive and inviting.	0	0	0	0
49.	The proximity of grade level and department personnel allows for ease in collaborating with colleagues.	0	0	0	0
50.	Communication systems promote a flow of information among staff members.	0	0	0	0
51.	Communication systems promote a flow of information across the entire school community including: central office personnel, parents, and community members.	0	0	0	0
52.	Data are organized and made available to provide easy access to staff members.	0	0	0	0
COMMENTS:					

Source: Olivier, D. F., Hipp, K. K., & Huffman, J. B. (In progress). Assessing and analyzing schools as PLCs. In K. K. Hipp & J. B. Huffman (Eds.). *Professional learning communities: Purposeful Actions, Positive Results.* Lanham, MD: Rowman & Littlefield.

APPENDIX E:1

Professional Learning Community (PLC) Pre-Meeting - Open-Ended

Purpose: Please answer the following questions. Answers will be collectively used to design the PLC for science departmental goals and needs.

- Have you previously participated in a Professional Learning Community or any other Learning Community? No Yes
  (if yes please list below)

- What is your current understanding of a Professional Learning Community?

- What are your current expectations for the Science Department Professional Learning Community?

- Please include comments/concerns regarding the current science curriculum at the Middle School.

APPENDIX E:2

Professional Learning Community (PLC) Meeting 1 – Open-Ended

Purpose: Please answer the following questions. Answers will be collectively used for design of the PLC for science departmental goals and needs.

- Have you previously participated in a Professional Learning Community or any other Learning Community? No Yes

- What is your current understanding of a Professional Learning Community?

- Considering the first speaker, what are your current expectations for the Science Department Professional Learning Community?

- Please include comments/concerns regarding the current science curriculum at the Middle School.

APPENDIX E:3

PLC Meeting Open Ended Questions

1. What are your current understandings of the science curriculum concerns at the middle school?

2. Considering today's presenters, what are your expectations for the Science Department Professional Learning Community?

3. How can you see the science department utilizing any of the information from today's PLC to aid in our curriculum change efforts? Explain.

4. What comments or suggestions for the PLC do you have as we progress towards grade level analysis?

APPENDIX E:4

PLC Post- Meeting Open-Ended Reflection

What are your current understandings of the science curriculum concerns at the middle school?

What is your understanding of a Professional Learning Community?

What was the mission / vision of the PLC?

Where the guest speakers worthwhile when considering the departments goals? Please Explain.

In what ways has the PLC accomplished its objectives?

In what ways has the PLC not accomplished its objectives?

What has been the most satisfying aspect of the PLC?

What has been the most disappointing aspect of the PLC?

Would you recommend the use of PLC to other education departments? Please explain.

APPENDIX E:5

PLC Meeting Focus Questions

Throughout the meeting and discussions have the participants answer the questions in either Option 1, 2 or 3 and collect answer at the end of the PLC meeting. The focus questions will be used to identify implications for the next PLC meeting.

PLC Meeting Focus Questions Option 1

Directions: Throughout the meeting and discussions, answer the questions. The focus questions will be used to identify implications for the next PLC meeting.

1. So far, what is the most important thing you have gotten from the Learning Community?

2. What important questions remained unanswered?

PLC Meeting Focus Questions Option 2

Directions: Throughout the meeting and discussions, answer the questions. The focus questions will be used to identify implications for the next PLC meeting.

1. What were the three most significant points discussed in this session?

2. What question would you like to pursue further?

PLC Meeting Focus Questions Option 3
Directions: Throughout the meeting and discussions, answer the questions. The focus questions will be used to identify implications for the next PLC meeting.

List any thoughts you may have regarding the grade level presentations:

What changes do we, as science department, want to make at this grade level?

What feasible changes could be made at this grade level?

Where should there be curriculum consistency?

How will we as a department, ensure that the changes proposed enhance student learning and work towards the department and PLC goal?

APPENDIX E:6

PLC Group Focus Reflection and Feedback questions

Directions: At the quarter points in the year have the PLC members complete a group feedback. Allow 10 minutes. The reflections will be used to identify implications for the next PLC meeting.

Group Reflection and Feedback Questions

1. List three aspects of the PLC that have been most effective in reaching towards the science departments visions?

2. Suggest one or two practical changes that could help improve movement towards the science department's vision?

APPENDIX F:1

Participant Informed Consent Forms

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525 West 120th St. * New York, NY 10027 * 212-678-3000

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Teachers College, Columbia University

INFORMED CONSENT

DESCRIPTION OF THE RESEARCH:

You are invited to participate in an independent research study involving the development of a Professional Learning Community (PLC) that would aid in the collaboration of the Scarsdale Middle School science teachers in their goal of middle school science curriculum development. The research goal is to document the process of the PLC in order to further research on the possible function and role of PLC in collaborative science department decision making particularly on science curriculum change.

As a participant you will be asked to join the PLC and you will be invited to attend several PLC meetings (of which there will be 3-4 over a period of 8 months, each meeting about 1-2 hours in length). A survey and reflection question will be giving to participants at each meeting and submitted anonymously. Meetings as well, will be audio-taped. The tapes will be transcribed for accuracy of information, again no names will be transcribed and all audio records and transcripts will destroyed at the conclusion of the research. Your name will not be used and data collected will be anonymous. All collected data will be secured at a safe and separate location, contain no identifiers, and with restricted access to the principle investigator and researcher. Collected data in the form of surveys, reflections, artifacts, and PLC meetings will be used solely for investigating the research goals, thus for the purpose of tracking the PLC.

Research will be conducted by [redacted] at Columbia Teacher's College) [redacted] Education Department at Colum[redacted]

[redacted]

RISKS AND BENEFITS: The risks and possible benefits associated with this study are outlined below:

Participation in this study involves potential minimal risk. Possible risks could include the invasion of privacy or breach of confidentiality. To reduce the risks of a break in confidentiality, no names will be used on assessments, surveys will be anonymous, pseudonyms will be used in all field notes and transcripts, all data will be kept in a locked file cabinet drawer at a separate location, and audio-tapes and transcripts will be destroyed at the conclusion of the research. Any identifiers will be eliminated. In efforts to prevent judgment or prejudice against subjects, identifiers will be removed and coded data kept in separate and secure locations. The subject population is small and specific to a particular department within a particular middle school; identification of subjects is not likely to occur outside of the population but must be considered. Because participants are colleagues, the sharing of personal opinions and information within the population will not allow for confidentiality to be guaranteed. In the event that data is lost, stolen, or otherwise compromised, lack of identifiers, codes, and pseudonyms will prevent subject's identification. All audio-taped meeting records will be destroyed after transcription and transcriptions will be destroyed after analysis for the independent study. Every effort will be made to remove identifiers and use codes and to protect confidentiality and animosity of subjects, therefore the likely hood of risks are reduced to minimal potential of occurrence.

Participation in this study involves no direct benefits to the individual participants. The potential benefits from this study are for the science department curriculum development and for literature on PLC. The development of a PLC could aid collaboration of the middle school science teachers and science curriculum development. When considering the needs of the middle school science department, the creation of a PLC seemly may fit and aid the department goals of science curriculum change. If the PLC is successful, the process may be of use and of value to other departments (of all subject types) in meeting their collaborative curriculum goals.

Participation in this independent study is voluntary and refusal to participate will not jeopardize status or employment. Participation in the study would involve agreeing to the PLC meetings, pre- and post- assessments, surveys, and reflection questions. Participants may withdrawal from the study at anytime without explanation or repercussions. Those who choose to participate in the PLC will be invited to attend several PLC meetings (of which there will be 3-4 over a period of 8 months, each meeting about 1-2 hours in length). A survey and reflection question will be giving to participants at each meeting and submitted anonymously. Meetings as well will be audio-taped. The meeting tapes will be transcribe for accuracy of information, again no names will be transcribed and all audio records and transcripts will destroyed at the conclusion of the research.

<u>PAYMENTS</u>: N/A

<u>DATA STORAGE TO PROTECT CONFIDENTIALITY</u>:

Collected data will include audio-recordings and transcriptions of the PLC meetings, pre-and post- assessment, participant surveys, and reflections. No names will be used on assessments, surveys will be anonymous, pseudonyms will be used in all field notes and transcripts, all data will be kept in a locked file cabinet drawer at a separate location. Audio-tapes and transcripts will be destroyed at the conclusion of the research. All collected data will be secured at a safe and separate location, contain no identifiers, and with restricted access to the research investigators. Any data stored on the computer will be password protected and encrypted. In the event that data is lost, stolen, or otherwise compromised, lack of identifiers, code usage, and pseudonyms will prevent subject's identification. Collected data in the form of surveys, reflections, artifacts, and PLC meetings will be used solely for investigating the research goals, thus for the purpose of tracking the PLC. Every effort will be made to remove identifiers, utilize codes, and securely store data in order to protect confidentiality and animosity of subjects.

<u>TIME INVOLVEMENT</u>:

Those who choose to participate in the research and PLC will be invited to attend several PLC meetings (of which there will be 3-4 over a period of 8 months, each meeting about 1-2 hours in length). Participants will complete a pre-assessment and post-assessment. A survey and reflection question will be giving to participants at each meeting and submitted anonymously. Therefore, the total time involvement for each participant will be approximately 8 hours over 8 months, this includes meeting and assessments.

<u>HOW WILL RESULTS BE USED</u>:

My research goal is to document the process the members of the PLC go through in order to enhance the lacking research on the possible function and role of PLC in collaborative science department decision making on curriculum change. My research is an independent case study being performed under the guidance on approval of Columbia Teacher's College. Coded data will be used for general trends and for the purpose of the independent research goals of tracking the PLC, not for individual participant analysis. The results will be used to complete a science education independent study with possible implications for a dissertation topic.

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PARTICIPANT'S RIGHTS

Principal Investigator: Christi Browne

Research Title: Professional Learning Community as a means for Science Curriculum Change

- I have read and discussed the Research Description with the researcher. I have had the opportunity to ask questions about the purposes and procedures regarding this study.
- My participation in research is voluntary. I may refuse to participate or withdraw from participation at any time without jeopardy to future medical care, employment, student status or other entitlements.
- The researcher may withdraw me from the research at his/her professional discretion.
- If, during the course of the study, significant new information that has been developed becomes available which may relate to my willingness to continue to participate, the investigator will provide this information to me.
- Any information derived from the research project that personally identifies me will not be voluntarily released or disclosed without my separate consent, except as specifically required by law.
- If at any time I have any questions regarding the research or my participation, I can [redacted], who will answer my questions. The investigator's phone number [redacted]
- If at any time I have comments, or concerns regarding the conduct of the research or questions about my rights as a research subject, I should contact the Teachers College, Columbia University Institutional Review Board /IRB. The phone number for the IRB is (212) 678-4105. Or, I can write to the IRB at Teachers College, Columbia University, 525 W. 120th Street, New York, NY, 10027, Box 151.
- I should receive a copy of the Research Description and this Participant's Rights document.
- If video and/or audio taping is part of this research, I (______________) consent to be audio/video taped. I (______________) do NOT consent to being video/audio taped. The written, video and/or audio taped materials will be viewed only by the principal investigator and members of the research team. Initials: ________________
- Written, video and/or audio taped materials (____) may be viewed in an educational setting outside the research (   ) may NOT be viewed in an educational setting outside the research.
- My signature means that I agree to participate in this study.

Participant's signature: ____
Date:____/____/____

Name: ____________________________

If necessary:
Guardian's Signature/consent: ______________________________
Date:____/____/____
Name: ______________________________

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Investigator's Verification of Explanation

I certify that I have carefully explained the purpose and nature of this research to ____________________________________ (participant's name) in age-appropriate language. He/She has had the opportunity to discuss it with me in detail. I have answered all his/her questions and he/she provided the affirmative agreement (i.e. assent) to participate in this research.

Investigator's Signature: ____

Date: _______________________

APPENDIX F:2

Confidential Participant Information

Please circle all that apply:

Years of Teaching: 1-3 4-6 7-10 11-14 15-18 19-22 23-25 26-29 30+

Years in Current District: 1-3 4-6 7-10 11-14 15-18 19-22 23-25 26-29 30+

Gender: Male Female

Ethnicity:

Hispanic

Asian

American Indian or Alaskan Native

Black or African American

Native Hawaiian or Other Pacific Islander

White / Caucasian

Other: ________________________

Prefer not to say

Highest Degree of Schooling or Education:

High School

College:

Bachelors Degree (BA, AB, BS)

Master's Degree (MA, MS, MEng, Med, MSW, MBA)

Professional Degree (MD, DDS, DVM, LLB, JD)

Doctorate Degree (PhD, EdD)

Other: ________________________

APPENDIX G:1

PLC Five Dimension Detail Descriptors

The 5 qualitative codes are described in detail below. Each code description is inclusive and outlines the types of data (types of actions, decisions, comments, dialogue, etc) that will be placed into or defined as representing each of the code categories. All code descriptions are research based (DuFour et al., 2005; Giles & Hargreaves, 2006; Hord, 2009; Oliver, Hipp, & Huffman, 2003; Scribner et al., 1999; Stoll et al., 2006;). Codes will be set with descriptors using the software data analysis tool Dedoose. Categories will reflect the appearance or lack of the following code descriptors:

<u>Dimension 1: Shared and Supportive Leadership</u>

(1) Shared and supportive leadership – is the determined by the presence or lack of the following:

- Department members are consistently involved in discussing and making decisions about most departmental issues
  - Group members question, investigate, and seek solution
  - Department members make suggestions to solve departmental goals
- The administrators incorporate advice from department members to make decisions
- The department members have accessibility to key information
- The department head and administration is proactive and addresses areas where support is needed
- Opportunities are provided for the department to initiate change
  - Leaders work to implement new policy and practice
  - Administrators provide necessary organizational and structural support for collaborative work
- The administrators share responsibility and rewards for innovative actions
- The administration participates democratically with the department sharing power and authority
  - Role of omnipotent department head is replaced by shared decision making and shared department problem solving
  - Administrators display willingness to participate in collective dialogue without dominating
  - Administrators share decision-making responsibility with the staff
- Leadership is promoted and nurtured among department members

- Leadership roles taken on by various members of the PLC
- o Decision-making takes place through committees and communication across grade and subject areas
  - Department members use multiple sources of data to make decisions about teaching and learning
- o Stakeholders assume shared responsibility and accountability for student learning without evidence of imposed power and authority

<u>Dimension 2. Shared Values and Vision</u>

(2) Shared values and vision – is the determined by the presence or lack of the following:

- o A collaborative process exists for developing a shared sense of values among the department
  - Teacher efficacy and norms of behavior: self-ware, self-critical, and increasingly effective professional organization, using the PLC to seek ongoing renewal and improvement
- o Shared values support norms of behavior that guide decisions about teaching and learning
  - Sense and understanding of purpose
- o Department members share visions for school improvement that have undeviating focus on student learning
  - Colleague support of objectives and learning outcomes
- o Decisions are made in alignment with the schools/departments values and vision
- o A collaborative process exists for developing a shared vision among the department
  - Shared vision, goals, objectives, learning outcomes of PLC members
- o School goals and department goals focus on student learning beyond test scores and grades
  - Focus of student learning and student learning outcomes
- o Policies and programs are aligned to the schools/departments visions
- o Stakeholders are actively involved in creating high expectations that serve to increase student achievement
  - Reflection of values of departments and school community and culture
- o Data is used to prioritize actions to reach a shared vision
  - Shared vision guide decisions about teaching and learning

Dimension 3: Collective Learning and Application

(3) Collective learning and application – is the determined by the presence or lack of the following:

- Department members work together to seek knowledge, skills and strategies and apply this new learning to their work
  - Collective learning and collective knowledge creation
- Collegial relationships exists among staff members that reflect commitment to school improvement efforts
  - Strengthen the bond between administration and teachers and their increasing commitment to improvement efforts
  - Pedagogy that establishes relevance of the curriculum and student engaged in learning activities that respond to their cultures and learning needs
- Members plan and work together to search for solutions to address diverse student needs
  - The creative and appropriate solution to problems
- A variety of opportunities and structures exist for collective learning through open dialogue
- Members engage in dialogue that reflects a respect for diverse ideas that lead to continued inquiry
  - Focus on areas of significant school improvement – curriculum, instruction, assessment, and the school's culture
- Professional development focuses on teaching and learning
  - Seeking of best strategies and instructional practices to engage student learning, adjust for dives learner needs
- Department members and stakeholders learn together and apply new knowledge to solve problems
- Department members are committed to programs that enhance learning
  - Collective responsibility for student learning
  - Commitment to high standards – responsibility of members to endure high achievement for all students
- Department members collaboratively analyze multiple sources of data to assess the effectiveness of instructional practices
- Members collaboratively analyze student work to improve teaching and learning

Dimension 4: Shared Personal Practice

(4) Shared Personal Practice – is the determined by the presence or lack of the following:

- Opportunities exist for staff members to observe peers and offer encouragement
  - Study and review of teacher practice
  - Examination of teachers' practice

- Staff members provide feedback to peers related to instructional practices
  - Reflective dialogue on pedagogy
  - Sharing of teaching practices
- Department members informally share ideas and suggestions for improving student learning
  - Multiple avenues of interaction among educators and promoting inquiry-oriented practices while working toward high standards of student performance
  - Conversation of problems in the application of new knowledge
  - Joint planning and curriculum development
  - Applying new ideas and information to problems solving and solutions addressing pupils' needs
- Staff members collaboratively review student work to share and improve instructional practices
  - Increased commitment to work
  - Case study analysis
- Opportunities exist for coaching and mentoring
- Individuals and teams have the opportunity to apply learning and share the results of their practices
  - Direct links and connection to classroom practices
  - Seeking new knowledge
  - Sharing of new knowledge through interaction
- Department members regularly share student work to guide overall improvement
  - Conversations about serious educational issues

Dimension 5: Supportive Conditions

(5) Supportive Conditions – is the determined by the presence or lack of the following:

- Supportive Relationships:
  - Caring relationships exist among staff and students that are built on trust and respect
    - Sense of interdependence
    - A collaborative environment
    - Collegial relationships – like positive educator attitudes, widely shared vision or sense of purpose, norms of continuous critical inquiry and improvement, respect, trust, and positive, caring relationships
  - A culture of trust and respect exists for taking risks
    - Mutual trust, respect, and support
    - All members given voice and respect

        - Development of norms to allow for difference, disagreement, variant interpretations, and debate in order to bring about improvement
    - o Outstanding achievement is recognized and celebrated regularly in our school
    - o Department members and stakeholders exhibit a sustained and unified effort to embed change into the culture of the school
        - Administrative support
        - Administrative involvement
        - Acceptance of shared purpose and goals
        - Change is unachievable without collaboration
    - o Relationships among members support honest and respectful examination of data to enhance teaching and learning
        - Joint review and feedback
        - Growth and development of the community
- Supportive Structures
    - o Time is provided to facilitate collaborative work
        - Supportive structures: use of time, communication procedures
    - o The school schedule promotes collective learning and shared practice
        - Staff involved in the development of activities and curriculum
        - Necessary time and resources to allocate learning, problem solving, and decision-making
    - o Fiscal resources are available for professional development
    - o Appropriate technology and instructional materials are available to staff
    - o Resource people provide expertise and support
    - o Facility is clean and inviting
    - o Proximity of grade level and department personal allows for ease of collaboration
    - o Communication systems ease flow of information
    - o Communication systems promote flow of information across entire school and community

Each codes appearance, frequency, or lack there of will be identified over the expanse of the PLC study.

APPENDIX G:2

Table of Coded Dimensions Distinguishing Characteristics

The table below summarizes the distinguishing characteristics used to identify each of the codes.

Coded Dimensions	Distinguishing Dimension Characteristics
(1) Shared and Supportive Leadership	- Administrators shares important information with teachers - Collaborative dialogue results from administrators seeking advise, counsel, and critical analysis from teachers - Administrators involve teachers in the discussion of and decisions made about department issues
(2) Shared Values and Vision	- Vision for improvement are discussed by PLC members - A vision is developed that represents a shared consensus of PLC members values - Vision is focused on improved students, teaching, and learning
(3) Collective Learning and Application	- Members participate in discussion of school teaching and learning issues / concerns - Members make plans of curriculum, pedagogy, and assessment to address changes in teaching and learning - Members assess, discuss, and reflect on implemented changes
(4) Shared Personal Practice	- Members share lessons, activities, curriculum, and pedagogy - Members share and provide feedback about each others teaching and learning - Members engage in mentoring or coaching to improve teaching and learning
(5) Supportive Conditions [Relationships]	- Protocols and strategies are used to encourage member communication and positive interaction and feedback - Trust is displayed through openness and willingness to share both positive and negative change experiences - Caring, collaborative, and productive relationships are displayed through comments of recognition and encouragements
(5) Supportive Conditions [Structural]	- Time is allotted for teachers to work and share information regarding teaching and learning improvements - Appropriate site and facility is provided to encourage proximity and interaction of PLC - Appropriate resources (funding, people, communication) are made available to aid PLC collaboration

Coded Dimension Characteristics for Qualitative Descriptors. All code descriptions are research based (DuFour et al., 2005; Giles & Hargreaves, 2006; Oliver, Hipp, & Huffman, 2003; Hord, 2009; Scribner, et al., 1999; Stoll et al., 2006;).

APPENDIX G:3

PLC Coded Dimension Rubric for Positive and Negative Distinguishing Characteristics

Coded Dimensions	Positive Distinguishing Characteristics	Negative Distinguishing Characteristics
(1) Shared and Supportive Leadership Shared and supportive leadership occurs when the traditional role of the administrator is broken down and redistributed to the learning community as seen through collaborative dialogue and shared responsibility of decision making.	○ Science administrators shares important information with teachers ○ Collaborative dialogue results from administrators seeking advise, counsel, and critical analysis from teachers on specific topics or questions ○ Statements that the resulting decisions from the discussion will be brought back to be implemented by science administrators	○ Staff members indicate that they are unaware and not involved in departmental issues and decisions ○ Staff members are told of decisions that have been made ○ Science Administrator holds the majority of leadership, power and authority throughout a discussions or whole meeting
(2) Shared Values and Vision The PLC engages individual values and works to develop a communal commitment to improved student learning	○ Vision for improvement in science education are discussed by PLC members ○ The vision is revisited and revised based on a shared consensus of PLC members values ○ Discussion about vision is focused on improved students, teaching, and learning in science	○ Staff members indicate that they are not aware of a unified departmental vision ○ Staff members indicate that they are not making decisions according to the department vision (but for other reasons?) ○ Individual staff members indicate that their own visions of science do not align to departmental vision
(3) Collective Learning and Application The PLC functions to encourage its members to collectively seek new knowledge and information as well as ways of applying that knowledge to teaching and learning	○ Majority of the members participate in discussion of school teaching and learning issues / concerns ○ Indication of any member making plans of curriculum, pedagogy, and assessment to address discussed changes in teaching and learning ○ Members assess, discuss, or reflect on changes implemented as a result of PLC discussions	○ Staff members refrain from engaging in and participating in discussions of teaching and learning issues and concerns ○ Members do not work together nor do they make plans to work together outside of the PLC to change curriculum, pedagogy, and assessments to address improvements
(4) Shared Personal Practice The sharing of practice occurs when teachers work together to plan, reflect, refine, and assess curriculum and instructional strategies used to work towards enhancing student-learning outcomes.	○ Members share lessons, activities, curriculum, and pedagogy ○ Members share and provide feedback about each others teaching and learning ○ Members offer to engage in mentoring or coaching outside of the PLC to improve teaching and learning	○ Members do not take opportunities to share examples of lessons, activities, curriculum and pedagogy (formally or informally) ○ No members provided feedback or reflection regarding each others teaching and learning for the purpose of improvement ○ Coaching or mentoring opportunities outside the PLC either denied or not offered or discussed.

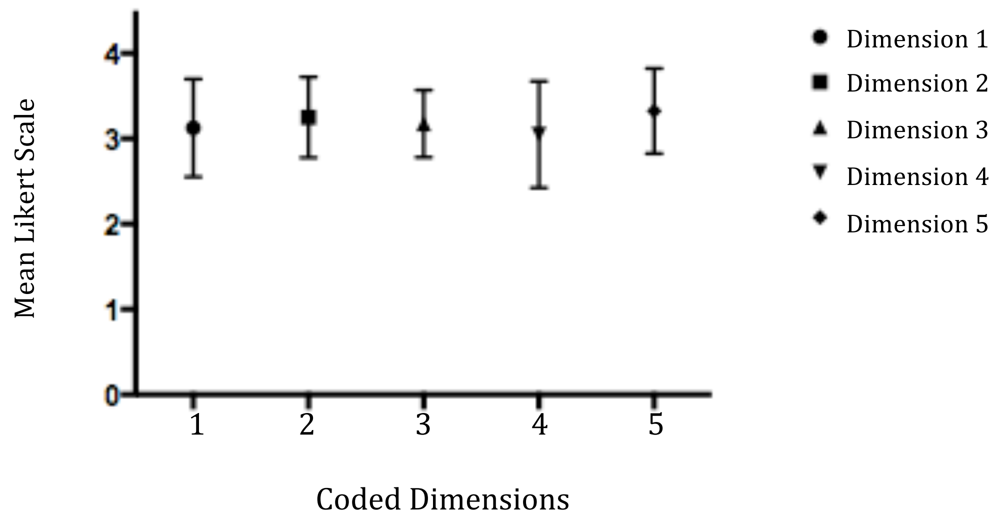
Coded Dimensions	Positive Distinguishing Characteristics	Negative Distinguishing Characteristics
(5) Supportive Conditions (Relationships) Supportive relationships are demonstrated via positive and encouraging dialogues and will be displayed via positive educator attitudes, widely shared and supported vision and PLC purpose, norms of critical analysis and inquiry, respect, trust, and positive, caring relationships.	○ Protocols and strategies are used to encourage member communication and positive interaction and feedback ○ Sharing of both positive and negative feedback (indicating trust in the group) ○ Supportive relationships are displayed through comments of recognition and encouragements	○ Lack of trust and respect between members is indicated by only negative or demeaning responses, or lacking sensitivity for feelings ○ Members exhibit a refusal of change improvements suggestions in science ○ Lacking is the acknowledgment, recognition, and encouragement of others achievements
(5) Supportive Conditions (Structural) Structural conditions are reflective of the positive use of time, communication procedures, proximity of teachers, size of PLC, and professional development.	○ The PLC meeting structure allotted time for teachers to work and share information regarding teaching and learning improvements ○ Appropriate site and facility is provided to encourage proximity and interaction of PLC ○ Appropriate resources (funding, people, communication) are made available to aid PLC collaboration	○ Members complain of "time" as an impediment to working together within or outside the PLC on teaching and learning improvements ○ Space or facility design discourages members from collaboration ○ Needed/desired resources are lacking (funding, people, communication systems)

APPENDIX H:1

Quantitative Analysis Performed

	Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5
Number of values	4	4	4	4	4
Minimum	2.3	2.6	2.6	2.3	2.6
25% Percentile	2.525	2.75	2.775	2.425	2.8
Median	3.3	3.4	3.3	3.1	3.5
75% Percentile	3.55	3.6	3.45	3.625	3.675
Maximum	3.6	3.6	3.5	3.7	3.7
Mean	3.125	3.25	3.175	3.05	3.325
Std. Deviation	0.5737	0.4726	0.3948	0.6245	0.4992
Std. Error of Mean	0.2869	0.2363	0.1974	0.3122	0.2496
Lower 95% CI of mean	2.212	2.498	2.547	2.056	2.531
Upper 95% CI of mean	4.038	4.002	3.803	4.044	4.119
One sample t test					
Theoretical mean	0	0	0	0	0
Actual mean	3.125	3.25	3.175	3.05	3.325
Discrepancy	-3.125	-3.25	-3.175	-3.05	-3.325
95% CI of discrepancy	2.212 to 4.038	2.498 to 4.002	2.547 to 3.803	2.056 to 4.044	2.531 to 4.119
t, df	t=10.89 df=3	t=13.75 df=3	t=16.09 df=3	t=9.768 df=3	t=13.32 df=3
P value (two tailed)	0.0017	0.0008	0.0005	0.0023	0.0009
Significant (alpha=0.05)?	Yes	Yes	Yes	Yes	Yes
Wilcoxon Signed Rank Test					
Theoretical median	0	0	0	0	0
Actual median	3.3	3.4	3.3	3.1	3.5
Discrepancy	-3.3	-3.4	-3.3	-3.1	-3.5
Sum of signed ranks (W)	10	10	10	10	10
Sum of positive ranks	10	10	10	10	10
Sum of negative ranks	0	0	0	0	0
P value (two tailed)	0.125	0.125	0.125	0.125	0.125
Exact or estimate?	Exact	Exact	Exact	Exact	Exact
Significant (alpha=0.05)?	No	No	No	No	No
Coefficient of variation	18.36%	14.54%	12.43%	20.48%	15.01%
Sum	12.5	13	12.7	12.2	13.3

Dimension Means Scores with Standard Deviations



APPENDIX H:2

Justification of Quantitative Analysis Performed

Frequency Distributions. In order to identify the number of data points falling into each of the set codes (5 dimensions of PLCs), frequency distribution data tables will be organized and displayed. This is the initial means of interpreting the individual codes and the possible relations of the codes to the PLC and each other.

Mean. The mean of each code will be used as a measure of central tendency and is affected by both number and magnitude of the coded data. From the mean comparisons of each separate code relation of each dimension to the PLC can be interpreted.

Standard Deviation. The standard deviation will put the data in the units of the original codes (dimensions). This will provide the means of identifying the relations between each of the set coded dimensions. The standard deviation will allow for the measure of set code dispersion. With a known standard deviation the confidence intervals for the mean of the sample can be calculated as well. The confidence interval is the probability that the interval estimate will be located within the population parameter, assuming normal distribution due to the sample size. The use of the t-distribution will allow for the identification of the standard error of the mean and the construction of a 95% confidence interval.

***t* Test**. The *t* test compares the means of two groups. The t test compares one variable between two groups.

APPENDIX I:1

Middle School Science Grade 6 – 8 Scope and Sequence Outlines

Scope and Sequence Grade 6

Unit Topic / Concept	**Amount of Class Time**	**Major Concepts Covered**
1. The Scientific Process	20 days	- Definition of Science - Using Senses - Observations: Qualitative and Quantitative - Inferences - Identifying and designing a Scientific Problem - Scientific Method and Problem Solving - Hypothesis formation and writing - Identifying Variables -Graphing
2. Inquiry Water Unit	26 days	- Properties of water -Trout and Water - Water distribution - Water Biomes - Water cycle - Watersheds -Water and Density
3. Ecology	55 days	- Living and nonliving - 5 Needs of Living Things - 7 Characteristics of Life - Parts of the Environment - Food and Energy Relationships - Food Chains and Food Webs and Energy Pyramids - Interaction within the environment (competition, predation, symbiosis) - Rhythms and Cycles in Nature (Nitrogen cycle and Carbon Cycle) - Man's Impact - Global Warming and Global Climate Change - Succession - Biogeography - Biomes - Adaptations and Evolution
4. Metric	20 days	- Measurement Systems

Measurement		- Metric Measurement - Metric Prefixes - Metric Conversions - Measuring Length - Measuring Area - Measuring Mass - Measuring Volume (regular and irregular shaped objects)
5. Physics	55 days	- Forces - Gravity - Air Resistance - Friction - Spring Scale - Pressure - Physics of Flight - Bernoulli's Principle - Motion and Frame of Reference - Speed - Velocity - Acceleration - Momentum - Newton's 3 Laws of Motion - Energy - Work - Power - Simple Machines - Compound Machines - Efficiency

Scope and Sequence Grade 7

Unit Topic / Concept	**Amount of Class Time**	**Main Concepts**
1. Introductory Topics	14 days	- Scientific method - Safety - Lab equipment - Microscope- parts & use - Microscopic measurement
2. Cells/ Life characteristics	11 days	- Cell parts & function - Life characteristics - Life processes

		- Difference between animal/plant/bacteria cell
3. Cell Processes	14 days	- Organic compounds - Transport - Photosynthesis - Cellular respiration
4. DNA / Mitosis	11 days	-Structure of DNA -Protein synthesis -Steps of the cell cycle -Cancer
5. Mendelian Genetics	12 days	- Mendel's work with pea plants - Genetic vocabulary - Using a punnett square - Incomplete dominance
6. Modern Genetics	22 days	-Multiple alleles -Sex determination -Nature vs. nurture -Genetic disorders -Genetic advances such as cloning, Genetic engineering -Genetic tools such as karyotypes *This includes a research project on genetic issues
7. Evolution	4	- Natural selection as a result of variation -Breeding Bunny (common assessment)
8. Classification/Bacteria/Viruses	15 days	-6 kingdoms & their characteristics - Linnaeus -Binomial nomenclature -Levels of classification -Dichotomous keys -General characteristics of bacteria -General characteristics of viruses -Vaccines
9. Protists/Fungi/Animals	11 days	- General characteristics of protist emphasizing amoeba, euglena, paramecia -General characteristics of fungi -General characteristics of the 9 animal phyla
10. Plants	12 days	-Plant classification- vascular/nonvascular

		-Structure & function of roots, stems, leaves, flowers & seeds -Steps of pollination -Self-pollination vs. cross pollination - Tropisms
11. Human Body Systems	app. 30 days	- Structure & function of the skeletal, nervous, digestive, respiratory & circulatory systems -Brief discussion of related diseases -Layers of skin -6 nutrients

Scope and Sequence Grade 8

Unit Topic / Concepts	Amount of class time	Major Concepts Covered
1. Introduction to Science	5 weeks	- Observation, inference, tools of science, measurement, scientific method, writing a lab report, variable, graphing, scientific notation, percent error, density, topographic maps
2. Chemistry	5 weeks	- Reading the periodic table, matter, elements, mixtures, solutions, compounds, nuclear energy, phases of matter, pH, chemical & physical changes
3. Rocks and Minerals	5 weeks	- Mineral ID, separating a mixture, rock cycle, types of rocks, serial dilution, elements to minerals
4. Earth's Interior	5 weeks	- Plate boundaries/movement, fossils (evidence for crustal movement), earthquakes, volcanoes, heat transfers
5. Shaping the Land	5 weeks	- Mining, landscapes, energy resources, soil, watersheds, weathering, erosion, deposition
6. Astronomy	5 weeks	- Gravity, density (review), orbits, phases of the moon, reasons for the seasons, constellations/star charts/types of stars
7. Meteorology and Oceans	5 weeks	- Reading a weather map, hurricanes, layers of the atmosphere, environmental issues with the oceans, relationship between oceans and weather, water cycle

8. 8th Grade Project	5 weeks	- Varies (2012: Passive Solar Homes Project)

APPENDIX I:2

Common Rubric for Progressive Science Skills Grades 6 – 8

	Exceeds Expectations	Expectations Met	Acceptable	Needs Improvement	Unsatisfactory
Title	Meets expectations and formatting is appropriate.	Describes relationship between independent and dependent variables in one statement.	Variables are mentioned but relationship is incorrect.	Lab title identifies some aspect of the lab.	Title is missing.
Background Information	Meets expectations and shows a depth of understanding.	Define and explain relevant terms, skills and content.	Background Information contains minor errors	Missing many components and/or fails to be relevant to the experiment.	Background is missing or plagiarized.
Problem Question	Meets expectations and problem posed in a testable question format and identifies a relationship.	Problem is correct but not posed as a question.	Problem posed contains minor errors	Problem unclear and/or fails to generate a relationship	Problem Question is missing.
Variable Identification	Meets expectations and identifies multiple constants (controlled variables)	All 3 variables correctly identified with only one constant identified. Control mentioned if applicable	2 of 3	1 of 3	Variables are not identified.
Hypothesis	Meets expectations and is posed as a testable 'if, then' statement. The hypothesis relates variables to be tested in the following way: "If [independent], then [dependent]"	Incorrect format or non-testable	Unclear or fails to relate to problem	N/A	Hypothesis is missing.
Materials	Meets expectations and lists appropriate materials with a greater specificity.	Appropriate materials are listed.	Materials list includes minor errors.	Materials listed are insufficient to complete the lab.	Materials are missing.
Procedure	Meets expectations and has additional pertinent detail (may include diagram)	Clear, concise step by step procedure capable of being duplicated with similar results	Procedure includes minor errors	Procedure is unrelated to experiment or insufficient	Procedure is missing.
Data Collection	Meets expectations and circumstances of collection is documented.	Data table is labeled, organized, and has proper titles and units. Rounding is appropriate.	Minor errors	Data is incomplete and insufficient to draw conclusions	Data is missing.
Data Analysis	Meets expectations and uses appropriate type of graph, Proper title, Independent variable and units on X-axis, Dependent variable and units on Y-axis, Scales appropriate for task, Graph shows appropriate trend.	Has between six or seven out of the eight components in Exceeds Expectations.	Has between four and six of the eight components	Has only one to four of the eight components	Data Analysis is missing.
Error	Meets expectations with increased detail and specificity and/or includes solutions to eliminate errors mentioned.	Identified possible and/or present errors that are appropriate but do not change the experiment	Errors are tangential and/or would change the experiment.	Errors are incorrectly identified.	Errors section is missing.
Conclusion	Meets expectations and additionally quotes / paraphrases external sources that bolster the validity of the conclusion with citation	Restates the hypothesis as a topic sentence. Briefly discusses the validity of the hypothesis and refers to data in order to validate / invalidate. States a conclusion (answer to the question) in a single sentence.	One component is unclear or missing	Two or more of the components are unclear or missing	Conclusion is missing or plagiarized.
Discussion	Meets expectations with detailed and thoughtful reflection with references to external sources	Expansion of the conclusion statement that incorporates real world scenario	Brief, superficial and / or limited	No real world connection and / or incorrect	Discussion is missing or plagiarized.

APPENDIX I:3

Middle School Science Department
Scientific & Engineering Practice Learning Progressions

Component	Level 4	Level 3	Level 2	Level 1	Aligned Lab activities
Asking questions for science and defining problems for engineering	Meets requirements for #3 and exceeds expectations.	Students generate a Problem and Hypothesis. Problem is in the form of a question and has a testable response. Hypothesis is in correct format and answers the Problem.	Missing at least one level 3 requirements.	Missing more than half of the level 3 requirements.	Physics final project and lab.
Developing & Using Models	Meets requirements for #3 and exceeds expectations.	Models provide an accurate representation. Scale is mathematically accurate.	Missing at least one level 3 requirements.	Missing more than half of the level 3 requirements.	Physic unit final project and lab. - Watersheds - Cycles of Nature
Planning and carrying out investigations	Meets requirements for #3 and exceeds expectations.	Scientific method is applied in stepwise fashion. Variables are correctly identified. Observations (qualitative or quantitative) are clearly descriptive.	Missing at least one level 3 requirements.	Missing more than half of the level 3 requirements.	Scientific Inquiry Labs and Design - Sink or Float
Analyzing & interpreting data	Meets requirements for #3 and exceeds expectations.	Data collection contains units of measure, appropriate rounding, and is relevant to the experiment. Data charts are organized with titles. Sources of error are appropriate to the	Missing at least one level 3 requirement.	Missing more than half of the level 3 requirements	Graphing Labs and Trout Observations

		experiment and clearly stated.			
Using mathematics and computational thinking	Meets requirements for #3 and exceeds expectations.	Graph shows recognition of variables and is appropriately labeled. Data is plotted accurately. Student demonstrates accurate extrapolation of data and/or correctly calculates slope. Proper usage of computer graphing programs, if applicable.	Missing at least one level 3 requirement.	Missing more than half of the level 3 requirements	Physics - Speed, Acceleration, Force, Velocity
Constructing explanations for science & designing solutions for engineering	Meets requirements for #3 and exceeds expectations.	Conclusion restates the validity of hypothesis and may allow for improvement in future trials. Predictions about the future (if applicable) are logical. Design solutions are an accurate representation of prior knowledge, including research.	Missing at least one level 3 requirements.	Missing more than half of the level 3 requirements	Machines and Simple Machines Measurement and Scientific Measurement Assessment
Engaging in argument from evidence	Meets requirements for #3 and exceeds expectations.	Student defends the conclusion with observations, data and/or discussion with peers.	Missing at least one level 3 requirements.	Missing more than half of the level 3 requirements	Climate Change Analysis
Obtaining, evaluating & communicating information	Meets requirements for #3 and exceeds expectations.	Students create a Journal and utilize their research appropriately.	Missing at least one level 3 requirements.	Missing more than half of the level 3 requirements.	Trout in the Classroom Journal

APPENDIX I:4

Alignment of Grades 6-8 to the *Framework for K-12 Science Education* (NRC, 2012)

PART 1. CORE AND COMPONENT IDEAS IN THE PHYSICAL SCIENCES

Disciplinary Core Idea	Component Ideas	Grade Level	SMS Curriculum connection	Notes
Core Idea PS1: Matter and Its Interactions	PS1.A: Structure and Properties of Matter	8	Grade 6 connection: Water unit – physical properties of water 8 - Introduction to Chemistry, Oceanography (water cycle) & Weather	- Solid, liquid and gas form of water
	PS1.B: Chemical Reactions	8	8 - Introduction to Chemistry	
	PS1.C: Nuclear Processes	8	8 - Introduction to Chemistry & Natural Resources	
Core Idea PS2: Motion and Stability: Forces and Interactions	PS2.A: Forces and Motion	6, 8	6 - Forces unit - force types, net force, measuring forces - Motion unit - Newton's Laws and Conservation of Momentum 8 - Astronomy (orbits & gravity)	- Needed is a new focus on prediction of motion - Needed is enhanced coverage of Law 3 and 2
	PS2.B: Types of Interactions	8	Grade 6 connection: Universal Gravitation	- Lacking electromagnetism, magnetic, and particle connections to interactions - Lacking force magnitude connected to charges, currents, and magnetic strength -Lacking electrical or magnetic field -Lacking electric charges and connection to atomic scale -Lacking Coulomb's law Lacking nuclear interactions

	PS2.C: Stability and Instability in Physical Systems	8		
Core Idea PS3: Energy	PS3.A: Definitions of Energy	8	-Grade 6 connection: Energy Unit – kinetic energy, potential energy, energy transfer, energy conservation, and energy in the ecosystem 8 - Heat Transfers/Convection Currents	- Needed is an increased focus on Energy Conservation - Lacking is electromagnetic radiation (light, radio, all waves) - Lacking thermal energy -Lacking electric and magnetic energy fields -Lacking temperature and energy connection - Note the different forms of energy are misleading and misleading to call sound and light energy
	PS3.B: Conservation of Energy and Energy Transfer	8	Grade 6 Connection: Energy Unit: conservation of Energy and Energy Transfer 8 - Heat Transfer/Convection Currents	-Lacking electric currents and heat transfer -Lacking absorption of heat energy - Lacking stable system and state - Needed is refocusing of motion energy changing other energy at the same time and the connection to friction -Needed is the connection of energy transfer to temperature changes = Lacking
	PS3.C: Relationship Between Energy and Forces	6	Grade 6 Connections: Forces Unit and Grade 6 Connection - Energy Unit: energy transfer	- Needed is connecting forces to the energy applied to the

				objects - Needed is the understanding that patterns of motion are the transformation of energy between the motion and stored energy - Lacking any connection to magnetic and electrical systems
	PS3.D: Energy in Chemical Processes and Everyday Life	8	Grade 6 connection – Energy Unit: energy transfer Energy in the ecosystem Unit: photosynthesis, food chains, and food webs Cycles of Matter Unit: Energy in the form of nutrients and chemicals cycles throughout the ecosystem Forces Unit: friction and lubricants 8 - Water Cycle/Oceanography/Climate & Heat Transfer/Convection Currents	- Our focus has been on energy stored and sourced in producers is passed throughout the ecosystem via food webs and energy is not destroyed by less is available at the top of the energy pyramid - Needed is an increased focus on energy transfer outside of the systems (including in friction and lubricant discussion) - Not covered by grade 6 is the chemical rnx and cellular respiration
Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer	PS4.A: Wave Properties	8	Grade 6 connection - Water Unit: Waves, tidal wave, tidal rhythms, lunar rhythms 8 - Earthquakes (P vs. S waves) & Heat Transfers	- Not covered: wave, waves and connection to energy transfer, light and sound; wave properties; electromagnetic radiation
	PS4.B: Electromagnetic Radiation			Not Covered
	PS4.C:	8	8 - Seismic waves	Not Covered

	Information Technologies and Instrumentation			- Needed is a connection to technology information

PART 2. CORE AND COMPONENT IDEAS IN THE LIFE SCIENCES

Disciplinary Core Idea	Component Ideas	Grade Level	SMS Curriculum connection	Notes
Core Idea LS1: From Molecules to Organisms: Structures and Processes	LS1.A: Structure and Function	7	6 connection- Ecology Unit: biotic-vs-abiotic, living – vs- nonliving 7 – Cells and body systems	
	LS1.B: Growth and Development of Organisms	7	7 – Cells to organisms (mitosis, meiosis), plants and animals	7 -Sexual Repro not taught in sci class
	LS1.C: Organization for Matter and Energy Flow in Organisms	6	6 - Energy in the Ecosystem: transfer of energy through food webs and energy pyramid	6 - Not covered is the chemical rnx to release energy
	LS1.D: Information Processing			
Core Idea LS2: Ecosystems: Interactions, Energy, and Dynamics	LS2.A: Interdependent Relationships in Ecosystems	6, 7	6 -Ecology Unit – Interaction with the Environment Unit and Energy in the Ecosystem Unit	6- Completely Covered
	LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	6, 7, 8	6 - Ecology Unit – Cycles of Matter and Energy in the Ecosystem 8 - Water Cycle & Rock Cycle	6 - Covered
	LS2.C: Ecosystem Dynamics, Functioning, and Resilience	6, 7	6 - Ecology Unit – Succession Unit and Biodiversity Unit	6 – Covered
	LS2.D: Social Interactions and Group Behavior	7	7 – Evolution of species and groups	6 - Not Covered
Core Idea LS3: Heredity: Inheritance and Variation of Traits	LS3.A: Inheritance of Traits	7, 8	7 – DNA replication, genes / chrom inheritance	
	LS3.B: Variation of Traits	7	7 – Punnett square and probability	

Core Idea LS4: Biological Evolution: Unity and Diversity	LS4.A: Evidence of Common Ancestry and Diversity	7, 8	Grade 6 connection – Interaction in the Environment: adaptation, evolution, natural selection and change over time 7 – Evolution – branching tree and common ancestors evidence 8 - Fossils	6 - Interdisciplinary connection with S.S. course – ancient man
	LS4.B: Natural Selection	7	Grade 6 connection – Interaction in the Environment: adaptation, evolution, natural selection and change over time 7 – Darwin and natural selection	6 - Define natural selection and say hello to Charles Darwin
	LS4.C: Adaptation	7	Grade 6 connection – Interaction in the Environment: adaptation, evolution, natural selection and change over time 7 – Enviro changes and helpful traits	6 - Define adaptation and compare and contrast with natural selection and evolution
	LS4.D: Biodiversity and Humans	6, 7 , 8	6 - Ecology Unit – Biodiversity and Human Impact 7 – Natural selection over time – changes that lead to pop changes 8 - Oceanography	6 - Covered

PART 3. CORE AND COMPONENT IDEAS IN EARTH AND SPACE SCIENCES

Disciplinary Core Idea	Component Ideas	Grade Level	SMS Curriculum connection	Notes
Core Idea ESS1: Earth's Place in the Universe	ESS1.A: The Universe and Its Stars	8	Grade 6 connection – Universal Gravitation: Why Earth is where it is? Earth Spins and Life Cycles: The spinning of Earth cause the rhythms and cycles of nature and influence the ecosystem: Daily Rhythms, Annual Rhythms (seasons), Lunar Rhythms, Tidal Rhythms, Biological Clocks, etc 8 - Astronomy Unit	
	ESS1.B: Earth and the Solar System	8	Grade 6 connections: Universal Gravitation, Sun is the source of Energy to the ecosystem; the moon cycle cause lunar rhythms	

			and tidal rhythms and tides; Earth's tilt causes the changes in the seasons which in turn are the cause of the annual rhythms; the sun's rays cause climates and biomes which cause biodiversity; human impact on the environment 8 - Astronomy Unit	
	ESS1.C: The History of Planet Earth	7 , 8	7 – Evolution (geological time scale) 8 - Natural Resources & Geologic Time	brief
Core Idea ESS2: Earth's Systems	ESS2.A: Earth Materials and Systems	6, 8	Interaction in the Ecosystems; Energy in the environment; Cycles of Matter 8 - Rock Cycle Unit, Astronomy	- Lacking is the connection Earth's history and microscopic systems
	ESS2.B: Plate Tectonics and Large-Scale System Interactions	8	8 - Rock Cycle Unit	
	ESS2.C: The Roles of Water in Earth's Surface Processes		Grade 6 Connection – Water Unit, Water Biomes, Water cycle 8 - Oceanography	- No coverage of weather and erosion due to water
	ESS2.D: Weather and Climate	8	Grade 6 Connection – Biomes and Climates; Carbon Cycle and greenhouse gases; Human impact on the environment – global climate change, pollution, prevention 8 - Climate & Weather	- No coverage of weather - Lacking any in depth coverage of influencing factors of climate
	ESS2.E: Biogeology	6, 8	6 - Cycles of Matter: the carbon cycle 8 - Natural Resources & Fossil Fuels & Fossils	- All major point reviewed through the lens of the carbon cycle
Core Idea ESS3: Earth and Human Activity	ESS3.A: Natural Resources	8	8 - Natural Resources	
	ESS3.B: Natural Hazards	8	8 - Weather, Rock Cycle Unit	
	ESS3.C: Human Impacts on	6, 7 , 8	6 - Human impact on the environment	6 - Focus on the environmental

	Earth Systems		7 – Pollution (water, land, air) 8 - Planet in Peril Unit	impacts (+/-) from human in the ecosystems 7- Human Rights Day
	ESS3.D: Global Climate Change	8	6 Connection – Carbon Cycle and Human impact on the environment 8 - Planet in Peril Unit	

PART 4. <u>CORE AND COMPONENT IDEAS IN ENGINEERING, TECHNOLOGY, AND APPLICATIONS OF SCIENCE</u>

Disciplinary Core Idea	Component Ideas	Grade Level	SMS Curriculum Connection	Notes
Core Idea ETS1: Engineering Design	ETS1.A: Defining and Delimiting an Engineering Problem	6, 8	Grade 6 connection – Scientific processing Unit 8 - Passive Solar Homes	- Lacking is the lens of the "engineer"
	ETS1.B: Developing Possible Solutions	6, 8	Grade 6 connection – Scientific Processing Unit 8 - Oil Spill Solutions, Passive Solar Homes	- Lacking is large scale testing of a model
	ETS1.C: Optimizing the Design Solution	6, 8	Grade 6 connection – Scientific Processing Unit 8 - Oil Spill Lab, Parachute Lab	- Needed is stronger focus on determining 'best' solution, optimization, and judgment
Core Idea ETS2: Links Among Engineering, Technology, Science, and Society	ETS2.A: Interdependence of Science, Engineering, and Technology	6, 8	Grade 6 connection – Scientific processing and measurement 8 - Passive Solar Homes, Oil Spill Lab & Planet in Peril Unit, Natural Resources	- Focus on instrument use and tools (metric rulers, balances, graduate cylinders) - Lacking is showing improved tech i.e. probes
	ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World	8	8 - Planet in Peril Unit, Mining, Natural Resources	

PART 5. ALIGMNET TO SCIENCE PRACTICES

PRACTICES FOR K-12 SCIENCE CLASSROOMS	SMS Grade Level Science Specific Examples
1. Asking questions (for science) and defining problems (for engineering)	6 - Research project and report – Global Climate Change 6 - Unit Connection: Scientific Processing 6 – Design Good Scientific questions 6 - Lacking is questions focused on empirical investigation) 7 – Paper Towel Lab 8 - Scientific Method Exam
2. Developing and using models	6 - Model to demonstrate energy flow throughout an ecosystem 6 - Model of the interaction between the cycles of mater 6 - Model to show/demonstrate how all of physics is happening all at once, not in isolation 6 - Unit connection: Scientific Processing: Graphing, Diagramming, Displaying Observations 6 - Unit connection – Ecology: use of computer simulations to analyzed environmental interactions and impact 6 - Lacking is discussion of model limitation and refinement 8 - Moon Pops, Solar Homes, Potable Water, Oil Spill Labs, Iceberg Lab, Density of Earth Lab, Serial Dilution Lab, Cookie Mining Lab, Timeline Activity, Radioactive Decay of M&M's, Abrasion Lab, Modeling Convection Currents Lab, Far Flung Fossils Lab, Imaginary Continent Lab, Hurricane Lab, Gravity Lab, ALL astronomy labs, Angle of Insulation Lab
3. Planning and carrying out investigations	6 - Fishy situation Lab – control variables and design own to identify why the fish moves 6 - Mystery Cans – design experiments and control variables to identify what is inside of the mystery cans

	6 - Unit Connection – Scientific Processing: the design and carry out of an investigation: hypothesis, questions, variables, controls, observation, inferences, and conclusion 7 – Human Skeleton / Cells / DNA 8 - Parachute Lab, Density of Earth Lab, Rubber Band Lab, Cookie Mining, Mineral ID Lab, Imaginary Continent Lab, Oil Spill Clean-up Lab, Rubber Band Lab
4. Analyzing and interpreting data	6 - Pooled data labs – Helicopters, inertia, ecosystem simulator – class data is pooled, graphed, interpreted through guided questions, and analyzed 6- Unit Connection - Scientific Processing – Scientific measurements and Graphing 7 – Paper Towel 8 - All 8th grade lab work
5. Using mathematics and computational thinking	6 - Graphing labs? 6 - Quantitative data collection 6 - Unit Connection – Scientific Processing: Scientific measurements and Graphing 6 - Lacking is any real connection to or analysis of mathematical algorithms 7 – Pedigree / Karyotype / Flower Forensics 8 - All 8th grade density labs, Great Gravity Lab, Oil Spill Lab, all labs that require creation or interpretation of graphs (varies), work on significant digits, graph interpretation on exams (varies), percent error work, Cookie Mining Lab, Radioactive Decay Lab, Earthquake Waves Lab, Electron Probability Lab
6. Constructing explanations (for science) and designing solutions (for engineering)	6 - Research Project and report – Global Climate Change 6 - Unit connection - Scientific Processing: the design and carry out of an investigation: hypothesis, questions,

	variables, controls, observation, inferences, and conclusion 6 - Lacking is student creation of more models to display their understanding of a phenomenon 7 – Bunnies 8 - All 8th grade labs where students are expected to write a conclusion paragraph (varies)
7. Engaging in argument from evidence	6 - Human Impact – the climate change debate 6 - Lacking is specific identification of weakness in an argument and evidence 7 – Genetic Eng 8 - See above. Also, end of the year 8th grade project self-evaluation
8. Obtaining, evaluating, and communicating information	6 - Project presentation and reflections 6 - Lacking is the use of scientific articles and critical analysis of science articles and claims 7 – Research Project 8 - Four formal lab reports chosen from the following: Drop Zone Lab, Abrasion Lab, Messing with Mixtures, Solar Home Lab, Drop of Oil Lab, Temperature vs. Pressure Lab

PART 6. ALIGNMENT TO THE CROSSCUTTING CONCEPTS

SEVEN CROSSCUTTING CONCEPTS OF THE FRAMEWORK	SMS Grade Level Science Specific Examples
1. *Patterns*	6 - Rhythms of Life – repeating patterns in nature 6 - Cycles of Matter 6 - Succession

	6 - Limiting factors 6 - F = ma 7 – Punnett Squares / Protein Syn – DNA – RNA / Mitosis 8 - Planet in Peril Unit, Angle of Insulation Lab, Rubber Band Lab, pH Labs, Mineral ID, Radioactive Decay Lab, Earthquake Waves Lab, Far Flung Fossils Lab, Imaginary Continent Lab, Global Winds Lab, Station Model Lab, Air Activities, Moon Phases Lab
2. *Cause and Effect: Mechanism and explanation*	6 - Identifying Variables 6 - Designing a hypothesis - predictions 6 - Creating data tables and graphs 6 - Physics – forces, motion, energy 6 - Newton's third law – Action/Reaction 7 – Bunnies / Flower Forensics / Pedigree Lab 8 - Planet in Peril Unit, Angle of Insulation Lab, Soda Density Lab, pH Labs, Density Labs, Phases of Matter Lab, Cookie Mining Lab, Abrasion Lab, Convection Currents Lab, Earthquake Waves Lab, Imaginary Continent Lab, Oil Spill Cleanup Lab, Global Winds Lab, Hurricane Prediction Lab, Temp vs Pressure vs Conditions Lab, Gravity Lab, Solar Homes
3. *Scale, proportion, and quantity.*	6- Environmental breakdown and size of Earth 6- Conservation of mass 6- Water Cycle (amount of fresh water availability); Carbon cycle (amount of CO_2 in the atmosphere) 6- Macro invertebrates – vs – micro invertebrates 6 - Scientific and metric measurement – metric conversions, scale of graduation 7 – Natural Selection / Fossils 8 - Density of Earth Lab, Entire Chemistry Introductory Unit, Cookie Mining Lab,

	Radioactive Decay Lab, Abrasion Lab, Convection Currents Lab, Earthquake Waves Lab, Far Flung Fossils Lab, Drop of Oil Lab, Iceberg Lab, Global Winds Lab, Hurricane Prediction Lab, Temp vs. Pressure vs. Conditions Lab, and Celestial Navigation Lab, How Big is Earth? Lab, Gravity Lab, Moon Phases Lab, Solar Homes
4. *Systems and system models*	6 - Demonstrations 6 – Diagrams – Earth's Cycles 6 – Enviro-scape Activitiy- Watersheds 7 – Human body 8 - Density of Earth Lab, Entire Chemistry Introductory Unit, Cookie Mining Lab, Radioactive Decay Lab, Abrasion Lab, Convection Currents Lab, Earthquake Waves Lab, Far Flung Fossils Lab, Drop of Oil Lab, Iceberg Lab, Global Winds Lab, Hurricane Prediction Lab, Temp vs. Pressure vs. Conditions Lab, and Celestial Navigation Lab, How Big is Earth? Lab, Gravity Lab, Moon Phases Lab, Solar Homes
5. *Energy and matter*	6 - Energy in the Environment – conservation of energy, energy pyramid, energy transfer 6 - Cycles of Matter – matter flow throughout the environment (abiotic and biotic) 6 - Energy of Motion – KE and PE, conservation of energy, and energy transfer 7 – Natural Selection / Bunnies 8 - Plate Tectonics, Phases of Matter Lab, Density Labs, Mixture Lab, Convection Currents Lab, Earthquake Waves Lab, Global Winds Lab, Solar Homes, Angle of Insulation Lab, Renewable vs. Nonrenewable Energy, Nuclear Energy Presentation, Electron Probability Lab

6. *Structure and function*	6 - Environmental breakdown – abiotic and biotic factors, limiting factors, carrying capacity 6 - Simple Machines 6 - Water unit 7 – Human Body 8 - Fossils notes
7. *Stability and change*	6 - Succession – focus on the continued change 6- Interaction in the environment – predator / prey relationships 6 - Motion – static friction 6 - Forces – balanced and unbalanced forces, net force affects 7 – Evolution 8 - Fossil notes, History of Earth Timeline, Powers of 10, Abrasion Lab, Far Flung Fossils Lab, Hurricane Predictions Lab